

# HISTORY AND CURRENT STATUS OF SYSTEMATIC RESEARCH WITH ARACEAE

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**Note:** This paper, originally published in *Aroideana* Vol. 21, pp. 26–145 in 1998, is periodically updated onto the IAS web page with current additions. Any mistakes, proposed changes, or new publications that deal with the systematics of Araceae should be brought to my attention. Mail to me at the address listed above, or e-mail me at [Thomas.Croat@mobot.org](mailto:Thomas.Croat@mobot.org). Last revised November 2004

## INTRODUCTION

The history of systematic work with Araceae has been previously covered by Nicolson (1987b), and was the subject of a chapter in the *Genera of Araceae* by Mayo, Bogner & Boyce (1997) and in Curtis's *Botanical Magazine* new series (Mayo *et al.*, 1995). In addition to covering many of the principal players in the field of aroid research, Nicolson's paper dealt with the evolution of family concepts and gave a comparison of the then current modern systems of classification. The papers by Mayo, Bogner and Boyce were more comprehensive in scope than that of Nicolson, but still did not cover in great detail many of the participants in Araceae research. In contrast, this paper will cover all systematic and floristic work that deals with Araceae, which is known to me. It will not, in general, deal with agronomic papers on Araceae such as the rich literature on taro and its cultivation, nor will it deal with smaller papers of a technical nature or those dealing with pollination biology. It will include review papers on technical subjects and all works, regardless of their nature, of current aroid researchers. It is hoped that other reviews will be forthcoming which will cover separately the technical papers dealing with anatomy, cytology, physiology, palenology and other areas, and that still another review will be published on the subject of pollination biology of Araceae and the rich literature dealing with thermogenesis.

Among the earliest papers featuring what are now called Araceae were those by L. Fuchs (1542) and John Ray (1682) who were among the first to fully describe plants of Araceae as well as those by Dodoens (1557) who described and illustrated several European species in *Arum*, *Arisarum* and *Dracunculus* (also featuring *Calla palustris* under the name *Dracunculus palustris*). Although these works often had aroids clustered together, and thus understood the familial concept, it was left to later works, especially Tournefort (1700) and Jussieu (1789), to define the Araceae in formal terms.

Carl Linnaeus, the father of binomial classification, can hardly be considered an aroid specialist, but since his system laid the groundwork for all subsequent work he must be recognized. His *Species Plantarum* (1753) treated only 26 of the more than 3500 species of Araceae currently estimated for the family, and these were placed in four genera: *Arum*, *Dracontium*, *Calla*, and *Pothos*. In *Genera Plantarum* (Linnaeus, 1754) he added the genus *Pistia*. By the time of his second edition of *Species Plantarum* (1763) he had recognized 36 species.

## EARLIEST SPECIALISTS WITH ARACEAE

### SCHOTT

Although a number of botanists, in addition to Linnaeus, worked with Araceae prior to the early 19th Century, Heinrich Wilhelm Schott was the earliest to specialize almost exclusively with Araceae. He began his studies in the late 1820s and continued until his death. Schott was born January 7, 1794, in Brünn (Brno), Moravia (now the Czech Republic). His father was the gardener for the botanical garden of the University of Vienna and Schott had early contact with well-known botanists, including J. N. and F. J. Jacquin. It was the latter who recommended the young Schott for a position on a trip to Brazil. While in Brazil from mid-1817 through 1821, Schott established and managed an introduction garden, made field trips, and prepared many notes concerning the plants and animals he saw. In 1845 he became Director of the Imperial Gardens at Schöbrunn palace in Vienna, succeeding N. J. Jacquin who had amassed a large collection of tropical aroids (Nicolson, 1987b). Schott remained at Schöbrunn until his death on March 5, 1865.

Schott's role in the Araceae would be difficult to surpass. He described most of the larger genera, including over one-third of those genera currently in use. Schott's work began with a series of short papers on Araceae (Schott, 1820, 1827, 1829a-g, 1830a-e) that he published as a series entitled *Für Liebhaber der Botanik* in a trade magazine entitled *Wiener Zeitschrift für Kunst, Literatur und Mode* [see also Anonymous, 1865]. Later he published a longer paper (Schott, 1832) in which he treated almost 40 genera, recognizing taxa at sectional and subfamilial levels. This paper was the first to deal at any serious level with aroid systematics. Following this paper, there was a 21-year hiatus in which he published only a few, short, relatively unimportant papers (Schott, 1851, 1852). However, rather than being inactive, Schott had been preparing his system of classification, commissioning drawings and paintings, and otherwise refining his classification system. Between 1853 and 1857 Schott published the first of his summary works, *Aroideae* (Schott, 1853-1857) that consisted of 60 plates. It was followed by his *Synopsis Aroidearum* (Schott, 1856) and *Genera Aroidearum* (Schott, 1858a), and finally by the *Prodromus Systematis Aroidearum* (Schott, 1860). He also published a series of lithographs in four fascicles (Schott, 1857–1858). During this very active period of his career, Schott also published a long series of very short, relatively less important papers (Schott, 1853a-c, 1854a-e, 1855a-g, 1857a-z,aa-nn, 1858b-i, 1859a-f, 1861, 1862a-d, 1863, 1864a-c, 1865a, 1865b). Most of these articles were published in the *Oesterreichisches Botanisches Wochenblatt*, a technical serial that appeared at a rate of sometimes more than one per week. In the year 1857, 43 Schott articles on Araceae were published!

The *Prodromus* brought his system of classification to a conclusion. Although Schott's herbarium collections (totalling 1379 specimens) were destroyed by fire shortly after the end of World War II, his incredibly detailed drawings of Araceae [commissioned by Schott], the *Icones Aroidearum*, remained and are now housed at the Vienna Natural History Museum. This set of 3400 line drawings (mostly herbarium specimens) and paintings of living collections were only partially published during Schott's lifetime. Only a few of the illustrations appeared in some of his works (Schott, 1853-1857; 1879a) but a complete microfiche edition of these illustrations has now been published (Schott, 1884) largely through the efforts of H. Riedl and D. H. Nicolson. One fascicle of plates containing Lasieae is lacking even today. In all, Schott described and named 587 species new to science. Among generic names still in use, he published 37 with an additional genus for which he made the transfer, and another for which he was the author of the basionym. No other aroid taxonomist has come close to Schott's

record at the generic level; Engler described eight still accepted genera and the only other competitors, Carl Lineaus and N. E. Brown, each have six currently recognized genera.

## CONTEMPORARIES OF SCHOTT

Schott had few contemporaries during his life that worked with Araceae, if only for a time. Foremost among these was Karl Sigismund Kunth, whose first publication (Kunth, 1818) dealing with observations on the genera of Araceae, even predated the work of Schott. Near the close of his career, Kunth published three short papers on Araceae (Kunth, 1841a, 1841b, 1842), and one large work, his *Enumeratio Plantarum* (1841a). The latter work alone described 90 new taxa. In all, he published as new or re-combined, 134 species of Araceae, more than any other aroid worker in his time. Other of Schott's contemporaries who dealt with Araceae include Karl Ludwig Blume, a German botanist employed by the Dutch, who published significant papers dealing with Asian, principally Malesian aroids (Blume, 1827, 1834, 1836-1837). Otto Kuntze produced an encyclopedic treatment of the Araceae in conjunction with his much broader work dealing with all families (Kuntze, 1891). A similar encyclopedic account was produced by C. Mueller (Mueller, 1858). Charles Gaudichaud-Beaupré (1826) published accounts of the Araceae collected on the voyage of M. Louis de Freycinet. D. N. F. Dietrich (1852) in his *Synopsis Plantarum* produced the last revision of Linnaeus's *Species Plantarum*. K. F. P. von Martius wrote a paper dealing with a number of morphological aspects of Araceae (Martius, 1831).

## KOCH

Perhaps more significant from the standpoint of Araceae was Karl Koch, a Berlin botanist whose first publication on Araceae (Koch, 1852, 1856) appears to have shocked Schott (who had obviously been slowly and meticulously accumulating information on Araceae without publishing it) into publication. Koch seemed to have a primary interest in Araceae but apparently did not have the depth of understanding possessed by Schott. Koch published mostly short articles (1852), sometimes including new species descriptions in gardening magazines such as *Allgemeine Gartenzeitung* (1857a-k) and *Wochenschrift für Gärtnerei und Pflanzenkunde* (1859, 1861, 1868; Koch & Veitch, 1863). Other new species were described in the seed lists of the Berlin Botanical Garden (Koch, 1853, 1854, 1855). Many of Koch's descriptions were based on cultivated plant material, often

of unknown origin. From the standpoint of the taxonomy of Araceae, it is tragic that all of his herbarium material was lost by war action; thus, in many cases it is now not possible to determine what he dealt with. Moreover, since Koch was one of the earliest aroid taxonomists many of his plant names are still valid. In all, Karl Koch described or re-combined 156 taxa.

## ENGLER

Schott was followed by the even more prodigious worker, Adolf Engler, who was born in 1844 [see biography by Diels (1931)]. Engler was 21 years old at the time of Schott's death and produced his first major publications in 1876 (Engler, 1876a-b), 11 years after Schott's death, while working at the Munich Botanical Garden. His first works entitled *Zur Morphologie der Araceen* (Engler, 1876a) and *Vergleichende Untersuchungen über die morphologischen Verhältnisse der Araceae* (Engler, 1876b) and several others (Engler, 1877, 1881b, 1883a, 1883c, 1884; Ray & Renner, 1990) dealt with development and emphasized one of Engler's major strengths, a good understanding of the anatomy, morphology and developmental processes in the Araceae. These fields were critical to the development of his system of classification (Engler, 1889a, 1889b).

Among Engler's earlier works was his treatment of the Araceae for Martius's *Flora Brasiliensis* (Engler, 1878a [other works, see below]). In this work Engler made the first modifications of the taxonomic system previously proposed by Schott. His treatment of the Araceae in A. & C. de Candolle's *Monographie Phanerogamarum* (Engler, 1879) followed shortly thereafter, and before the turn of the century, he had published a complete revision of *Anthurium* (Engler, 1898b [see also errata in Engler, 1898c]), *Philodendron* (Engler, 1899a), and *Dieffenbachia* (Engler, 1899b). He also published a number of papers (mostly in a series of papers entitled *Beiträge zur Kenntnis der Araceae*) describing miscellaneous genera and species, including those from America (Engler, 1878b, 1881a, 1885), from Africa (Engler, 1892, 1899c, 1905d, 1917; Engler & Krause, 1914, 1917); and from Asia (Engler, 1887b, 1889a, 1898a, 1901b, 1907; Engler & Krause, 1912, 1916a, 1916b, 1921, 1922). Some papers deal with Araceae worldwide (Engler, 1883b, 1883c, 1905b) or deal with more than one area, such as Africa and Asia (Engler, 1880, 1898a, 1898b), or Asia and America (Engler & Krause, 1916a, 1916b). Other papers describe the new genera *Protarum* (Engler, 1901a), and *Ulearum* (Engler, 1905c). Engler prepared descriptions (Engler, 1883a) of Araceae in a discussion of plants collected by O. Beccari in Malesia and

Papua New Guinea. Engler also published a major work on the phytogeography of the Araceae (Engler, 1909).

Aside from the major floristic work done for Brazil (Engler, 1878a) Engler conducted few floristic works. Exceptions are treatments that he did for other workers including Pittier (1898) for Costa Rica (Engler, 1900) and for J. Schmidt's *Flora of Koh Chang* (Engler, 1902). He also prepared descriptions of Araceae collected by O. Beccari in Malesia and Papua New Guinea (Engler, 1883a).

Although Engler's work was much more diverse than Schott's and involved many families, it can be said that Engler was, at heart, an aroid taxonomist. As Director of the Berlin School of Botany he directed and advised many other botanists and was responsible for the production of such works as *Das Pflanzenreich* and *Die natürlichen Pflanzenfamilien*, the latter prepared with Karl Anton Eugen Prantl. The Araceae treatment for this latter work was done by Engler (1887) himself. Engler apparently had much more material available than Schott had seen but he seems to have paid little attention to living material. Before his death in 1930 Engler prepared new revisions for all of the Araceae, down to the species level (Engler, 1905d, 1908, 1911, 1912, 1915, 1920a, 1920c; Engler & Krause, 1908, 1920). Many of these are still in use today and many are still the most recent taxonomic revisions. In all, he described more than 1100 taxa at or below the specific level. By the end of Engler's career the number of known species of Araceae had risen to 1800 from the 900 known at the time of Schott (Mayo *et al.*, in press).

## **BROWN**

Though playing a minor role compared to Engler, his contemporary, N. E. Brown also made important contributions to the study of Araceae. His long tenure at the Royal Botanic Garden, Kew left the herbarium literally spattered with his penciled notes on taxonomic problems with specimens. Included among these hand-written notes are tracings of Karl Koch's herbarium in Berlin (now lost). The interpretations and careful notes of N. E. Brown showed that he had a depth of understanding about many serious taxonomic problems that still face taxonomists today and his notes are still immensely useful. Brown also participated in the production of Araceae treatments for floristic works such as the *Flora of Tropical Africa* (Brown, 1901), described new genera (Brown, 1882a)

and numerous new species (Brown, 1880, 1886, 1903, 1912, 1913). In all, Brown published a total of six genera still in use and 135 new taxa.

## **KRAUSE**

Kurt Krause, who began working with Engler on January 1, 1905, was responsible for a few other small families in *Das Pflanzenreich* but soon became interested in the Araceae. He was assigned the task of revising Engler's 1899 treatment of *Philodendron* for *Das Pflanzenreich* (Krause, 1913) but aside from describing some new species (Krause, 1910, 1911a, 1911b, 1912, 1914a, 1914b, 1921, 1922, 1924a, 1925, 1927), he made few changes to the treatment. Together with Engler, he was responsible for the writing of the *Das Pflanzenreich* treatments of the Monsteroideae (Engler & Krause, 1908), Philodendroideae-Philodendrineae (Krause, 1913), and Colocasioideae (Engler & Krause, 1920); however, Krause completed the Calloideae alone (Krause, 1908). Active for some years after Engler's retirement, Krause published additional species after Engler's death (Krause, 1930, 1932a, 1932b, 1940, 1941, 1942; Krause & van Alderwerelt, 1924, 1927). In all Krause was responsible for describing 124 taxa and another 75 species in conjunction with Engler.

## **SODIRO**

Luis Sodiro, working at the turn of the century, described more than 281 taxa of Ecuadorian Araceae, mostly *Anthurium*, but also included one *Heteropsis*, six *Rhodospatha* and 15 *Stenospermation* (Sodiro, 1900, 1901a, 1901b, 1903, 1905a, 1905b, 1905c, 1906, 1907, 1908a, 1908b). Sodiro was the first botanist working with Araceae who could be considered a true field botanist and he spent most of his botanical career in the tropics of Ecuador. Born in Italy, Sodiro joined the Society of Jesus (Jesuits) and served in Ecuador until the time of his death. Working from the monastery at Cotocallao, now in the suburbs of modern Quito, Sodiro explored most of the area around Quito, especially the nearby slopes of Volcán Pichincha. His descriptions of Araceae were the first ever to show excellent detail, thereby making it apparent that the descriptions were prepared from live material or from copious field notes. Unfortunately, Sodiro had no concept of types and did not even number his collections. Another major impediment to studying Sodiro's material is that many of his first set of collections remain deposited in the herbarium of the Biblioteca Aurelio Pólit (QPLS) where the specimens are not available to be borrowed for study. For this

reason many of his species names remain poorly known.

Sodirol's publications are also troublesome because he frequently published the same species several times, sometimes making only slight changes in the manuscript from earlier versions. Dan Nicolson (1984a) has made a definitive study of Sodirol's publications and one must refer to it when dealing with Sodirol's collections. Despite these difficulties, the contributions made by Luis Sodirol were the greatest that ever have been made by any resident on the South American continent. Had he had time to extend his studies to other genera, especially *Philodendron*, it is impossible to imagine what his contribution might have been.

## REGIONAL STUDIES WITH ARACEAE

### ASIA

Among the earliest who described and often illustrated Araceae in Asia were the Dutchmen, H. A. van Rheede tot Drakestein (1688, 1692), who did massive studies of the Malabar coast of India; P. Hermann (1689), who produced the *Paradisus Batavus*; and G. E. Rumphius (1747), who studied the flora of the island of Amboina [one of the Mollucas Islands, now Maluku in Indonesia]. Another Dutch botanist, N. L. Burmann (1768), published Araceae in his *Flora Indica*, and C. L. Blume dealt extensively with Malesian Araceae (Blume, 1836-1837). Another early botanist who described and illustrated Araceae in Malesia was the Italian, Odoardo Beccari (Beccari, 1879, 1882, 1889; Engler, 1879b).

Many of the species in Asia were described by regional workers doing floristic studies on particular regions. Except for Japan the earliest workers with aroids in Asia were generally not natives but were primarily botanists from colonial powers working in their own sphere of influence. In the Dutch East Indies it was primarily the Dutch. Other botanists who were describing Araceae from the Dutch East Indies included the Britian, R. Brown (1810), the German, J. C. Hasskarl (Hasskarl, 1842), and Dutch botanists, J. E. Teijsmann (Teijsmann & Binnendijk, 1862), F. A. W. Miquel (Miquel, 1855-1856, 1856, 1860, 1864, 1867), Hans Hallier (1898, 1901, 1915), C. R. W. K. van Alderwerelt van Rosenburgh, thankfully abbreviated "Alderw." (Alderwerelt van Rosenburgh, 1920, 1922a, 1922b), and C. A. Backer (Backer, 1913a, 1913b, 1913c, 1914, 1920, 1928).



In Indochina, it was a Portuguese naturalist Joao Loureiro who published his *Flora Cochinchinensis* (1790) and the Frenchman, F. R. Gagnepain, who wrote the Araceae treatment for Lecomte's *Flore général de l'Indochine* (Gagnepain, 1942a) and other works describing new genera and species (Gagnepain, 1941a-c).

In the Malay Peninsula it was H. N. Ridley, Director of the Singapore Botanical Garden from 1888 to 1912 (Ridley, 1908, 1916, 1922, 1938), and C. X. Furtado (Furtado, 1930, 1935, 1939, 1941, 1958, 1964a, 1964b), also from Singapore who described Araceae in the area.

In the Philippines it was the Spaniard, F. M. Blanco (1837) and Americans, E. D. Merrill (1912, 1915, 1916a, 1916b, 1917, 1918, 1919, 1921b, 1923, 1924, 1925, 1926, 1932, 1935b, 1937, 1948, 1949, 1952) and A. D. E. Elmer (1919, 1938, 1939). Merrill also described species from Guam (Merrill, 1914), Borneo (Merrill, 1921a, 1922a, 1929); Sarawak (Merrill, 1922b, 1928, 1934a) and Hainan in China (Merrill, 1927, 1930a, 1930b; Merrill & Metcalf, 1945), Sumatra (Merrill, 1933) and Vietnam (Merrill, 1942).

In Malesia, much of the recent work with the flora was organized by C. G. G. J. van Steenis who began the *Flora Malesiana* project as a resident in Asia for much of his lifetime. Most of his studies were carried out on Java (van Steenis, 1948a, 1948c, 1949, 1965a, 1965b, 1972, 1975). Despite the fact that some of the earlier European workers, including Ridley and van Steenis, spent considerable portions of their lives in Asia the majority of the Asian species were described in the European centers of botany, in Paris, Brussels, Leiden, Berlin, and Kew.

At Kew, the role of describing Araceae was first played by William J. Hooker and his son Joseph D. Hooker (J. Hooker, 1883, 1904), the first two directors, and later by N. E. Brown (Brown, 1901) and to a lesser extent by M. T. Masters (1873, 1876, 1878, 1884, 1893a, 1893b, 1898). The elder Hooker played only a minor role dealing directly with Araceae but did publish a number of short papers in *Curtis's Botanical Magazine*. These dealt with *Alocasia* (W. Hooker, 1860b, 1863), *Amorphophallus* (W. Hooker, 1860a), *Arum* (W. Hooker, 1828), and *Pistia* (W. Hooker, 1851). J. D. Hooker dealt more extensively with Araceae. He was responsible for the treatment of the Araceae in Bentham & Hooker's *Genera Plantarum* (J. Hooker, 1883c), a treatment largely based on that of Schott. He also described many species of Araceae as well as the genus *Gonatopus*. Many

of his new species were described in his *Flora of British India* (J. Hooker, 1893). J. D. Hooker also treated many species in great detail in *Curtis's Botanical Magazine*, including *Aglaonema* (J. Hooker, 1865b), *Alocasia* (J. Hooker, 1865a, 1896), *Amorphophallus* (J. Hooker, 1888, 1891a, 1893b), *Arisaema* (J. Hooker, 1890a, 1890b, 1891b), *Colocasia* (J. Hooker, 1894), *Cryptocoryne* (J. Hooker, 1900), *Culcasia* (J. Hooker, 1869 [described as *Aglaonema*]), *Hapaline* (J. Hooker, 1893a), *Lysichiton* (J. Hooker, 1904), *Piptospatha* (J. Hooker, 1881b, 1895), *Schismatoglottis* (J. Hooker, 1881a), and *Typhonium* (J. Hooker, 1875).

Many other floristic studies, both regional and general, throughout many years have contributed to the generally high levels of knowledge about Asian plants. Owing to the early English involvement, many of the early floristic studies were made on the Indian subcontinent, including those in W. Roxburgh's *Flora Indica* (Roxburgh, 1820b, 1832) and in *Hortus Bengalensis* (Roxburgh, 1814) which cataloged the holdings of the East India Company's living collection in Calcutta. Other early works include those by the German A. W. Roth (1821) and the Dane N. Wallich (1830, 1831). Still other general works on India include those by Burkill (1925), Suresh *et al.* (1983) and Zhongguo (1994). Works dealing with specific parts of India include that for the Coromandel Coast [SE India] (Roxburgh, 1820a); Assam, South India (Rao & Verma, 1968, 1976; Barnes & Fischer, 1936a); the Calicut area (western sectors of Calicut and Malappuram Districts) (Manilal & Sivarajan, 1982); the Presidency of Madras (Fischer, 1931); the Howrah District (Bennet, 1979); the Presidency of Bombay (Cooke, 1906; Blatter & McCann, 1931); Nainital in Uttar Pradesh (Gupta, 1968), the Bashahr Himalayas (Nair, 1977); Manipur State [NE India] (H. Singh, 1993), the Chikihagular District, Karnataka, India (Bhat, 1993; Yoganarasimhan *et al.*, 1981); as well as of Majuli (Islam, 1990); Punjab (Sharma, 1990), Andaman and Nicobar Islands (Kurz, 1893; Srivastava & Kumar, 1993), Barren Island (Prain, 1893) and the Kolhapur District in Maharashtra State written by Indian Araceae expert S. R. Yadav and his colleague M. M. Sardesai (both from Shivaji University in Kolhapur District). C. Fischer published a series of papers during the 1930s dealing with Indian Araceae (Fischer, 1931, 1933, 1934, 1936a, 1936b, 1939) and F. Baius (1936) wrote on the medicinal and poisonous aroids of India. New species of *Arisaema* (Rao & Srivastava, 1991; Yadav *et al.* 1993) have been recently described from India (see also Sivadasan below).

Studies of Araceae in non-Indian areas on the Indian subcontinent include those in West Pakistan (Nasir, 1978); Bangladesh (Khan & Halim, 1987); Bhutan

(Noltie, 1994); Nepal (Wallich, 1824); Hara, 1978); Himalayas (Polunin & Stainton, 1984) and Eastern Himalaya (Hara, 1966). Araceae studies in areas adjacent to India include those in Ceylon (Thwaites, 1864; Trimen, 1898; Alston, 1931) and Burma (Kurz, 1873).

Elsewhere in Southeast Asia studies were made in Thailand (Ridley, 1911a; Craib, 1912, 1913; Hu, 1968; Suvatti, 1978) and the Malay Peninsula including West Malesia (Jack, 1820; Burkill & Holttum, 1923; Ridley, 1885, 1893, 1902, 1904, 1907a, 1907b, 1909, 1910; 1911a, 1911b, 1912, 1925a; Rendle, 1924-1925; Henderson, 1926, 1927, 1928, 1939, 1954; Merrill, 1952; Chin, 1982; van Steenis-Kruseman, 1963, 1966, 1975); Malaya [Perak] (Hemsley, 1887); Malaya (Johore) & Singapore (Corner, 1978); [Pahang, Gunung Ulu Kali] (Stone, 1981); Singapore (Ridley, 1900). Studies in Indochina were those by Gagnepain (1942a) and by Merrill (1935a); others were in Vietnam (Pham Hoàng Hô, 1960; Thin, 1997). Other studies were made in Borneo (Rendle, 1901; Ridley, 1905, 1913, 1914; Gibbs, 1914; Masamune, 1942); Sabah (Stapf, 1894); and Sarawak and Brunei (Anderson, 1963; Wong, 1990).

Additional works from the Dutch East Indies and vicinity included works by the following: de Vriese (1851); Miquel (1855–1856, 1956a, 1956b, 1860, 1864, 1867); Zollinger (1845, 1854, 1857); Soepadmo (1977); van Steenis (1949); other areas mostly Indonesia (Java, Sumatra, Celebes, Borneo, New Guinea and rarely the Philippines) by Alderwerelt van Rosenburgh (1920, 1922a, 1922b); Java (Thunberg, 1825; Hasskarl, 1842a, 1842b, 1844, 1848; Koorders, 1901a, 1901b, 1911, 1918a, 1918b, 1923; Backer, 1913a-c, 1914, 1920, 1928; Backer & Bakhuizen, 1968; Backer *et al.*, 1950; Bakhuizen v.d. Brink, 1957, 1963); Sumatra (Hotta, 1984; Ridley, 1917, 1923, 1925a, 1925b); Celebes (Koorders, 1898, 1922b; Kawakami, 1912); Tjibodas [Indonesia] (Koorders, 1922); Amboina [Indonesia] (Rumphius, 1747, 1750); Bangka (Kurz, 1864); Talaud Islands [Indonesia] (Holthuis & Lam, 1942) and Mentawi Islands [Indonesia] (Ridley, 1926), and finally Christmas Island [a British island south and west end of Java] (Rendle, 1900; Ridley, 1906).

Works in New Guinea included: (Ridley, 1886; Schumann & Hollrung, 1889; Schumann & Lauterbach, 1905; Engler, 1907, 1911; Engler & Krause, 1911; Rechinger, 1913; Ridley, 1916; Rendle, 1923; Borrell, 1989); Papua New Guinea (Gilli, 1980; Lane-Poole, 1925; Mueller, 1876b; Schumann, 1887; Warburg, 1891; White, 1922; White & Francis, 1927); Dutch New Guinea

(Gibbs, 1917); Bismarck Archipelago [Papua New Guinea] (Peekel, 1984) including New Ireland (Lauterbach, 1911) and New Britain (Schumann, 1898), and Kairiru Island [New Guinea] (Borrell, 1989).

In the Philippines works included are those by: Usteri (1905); Brown (1919); Quisumbing & Merrill (1928); Pancho (1959); and Hatusima (1966). [See also papers by E. D. Merrill and A. Elmer cited above].

In northern Asia studies were made in China (Li *et al.*, 1977); southwestern China (Handel-Mazzetti, 1936; Wu & Li, 1979); Hainan Province (Chun *et al.*, 1977), the Dulongjian region (Li, 1993b); Taiwan (Hayata, 1915, 1916, 1919, 1920; Liu & Chen, 1984; Liu & Huang, 1963, 1977; Huang, 1960, 1979, 1982, 2000; Masamune, 1943); Botel Tobago [ca. 75 km SE of Taiwan] (J. P. Hernández, 2002[2003]) and Korea (Lee, 1976; Lee, 1985). [See also the contributions by Merrill elsewhere.] In Japan most species of Araceae were described by T. Makino (1892, 1893, 1901a, 1901b, 1910a, 1910b, 1911, 1913, 1918a, 1918b, 1928, 1931, 1932, 1960, 1961) and T. Nakai (1917, 1918, 1928, 1929, 1931, 1934, 1935a-d, 1937a, 1937b, 1938, 1939a-c, 1940a-d, 1943). Other works from Japan included those by M. Honda (1939), S. Kitamura *et al.* (1977); G. Koidzumi (1928), T. Koyama (1965), J. Ohwi (1953, 1965), J. Ohashi (1982), and H. Tanaka (2004). Another dealt with Okinawa and the southern Ryukyu Islands (Walker *et al.*, 1976).

Floristic works and miscellaneous papers on Araceae in Australia include: general areas (Brown, 1810; Mueller, 1858, 1874, 1876a, Bentham, 1878; Maiden, 1889, 1905; Domin, 1911, 1915; Green *et al.*, 1994; Jones *et al.*, 1977; Pate & Dixon, 1982; Elliot & Jones, 1982, 1984, 1990; Morley, 1983; Jones *et al.*, 1977; Jones & Gray, 1988, Briggs & Leigh, 1988; Hnatiuk, 1990; Hay, 1989, 1992a, 1993a, 1993b, 1995); Queensland (Bailey, 1883, 1891, 1897, 1902, 1913, 1914; Orsino & Dameri, 1992; Williams, 1979); New South Wales (Moore & Betchie, 1893; Dixon, 1908; Evans, 1961, 1962; Hay, 1993c), Lord Howe Island (Oliver, 1916), Sydney region of New South Wales (Beadle *et al.*, 1963, 1982; Beadle, 1987); Carolin & Tindale, (1993); Victoria (Ewart, 1930; Willis, 1962); Central Australia (Jessop, 1981); South Australia (Black, 1909, 1943, 1978, 1986; Eichler, 1965; Jessop, 1986); Western Australia (Gardner, 1931); Kimberley region [Western Australia] (Rye, 1992); Northern Territory (Ewart & Davies, 1917; Blake, 1954; Lazarides *et al.*, 1988); Cocos Islands [north of Australia] (Prain, 1891); and Norfolk Island (Maiden, 1903).

The region of Oceania, though not rich in Araceae, has been well studied from the standpoint of aroid floristics. Among the earliest studies made in the region was that by J. G. A. Forster (1786) who made a floristic study of the so-called Australian Islands (Southern Islands, i.e. New Zealand, New Caledonia, and many of the smaller Oceanic islands. Still another early study was that by B. C. Seemann (1868, 1869a, 1869b) on Fiji. Other studies in the Oceanic region included that on the Samoan Islands (Christoffersen, 1935; Reinecke, 1898); Rarotonga [Cook Islands] (Wilder, 1931); the southeastern Moluccas (Hemsley, 1885b); Ryukyu Islands (Hatusima, 1962); Micronesian Islands (Koidzumi, 1916; Hosokawa, 1937; Hatusima, 1939; Kanehira, 1933, 1935); Makatea (Wilder, 1934); Guam (Safford, 1905; Stone, 1964); Tonga Islands (Hemsley, 1893; Yuncker, 1959; Hotta, 1963a; Whistler, 1991); Christmas Island (Rendle, 1900; Ridley, 1906); Niue [New Zealand] (Yuncker, 1943; Sykes, 1970); Kermadec [New Zealand] (Sykes, 1977; Parham, 1972), Ponape [Caroline Islands] (Glassman, 1952), New Hebrides (Guillaumin, 1932, 1938), and New Caledonia (Guillaumin, 1937, 1943, 1947, 1948, 1962; Rendle, 1921).

In contrast to much of Asia, the Japanese have largely studied their flora. Local Japanese botanists who made great contributions to the understanding of the Araceae include Tomitaro Makino (1862-1957) and Takenoshin Nakai (1882-1952) from the University of Tokyo and Director of the National Science Museum. Nakai described most species, mostly species of *Arisaema* and he also published a new system of classification (Nakai, 1943) that excluded a few long-standing genera of Araceae, incorporating them into their own families, Pistiaceae, Cryptocorynaceae, and Acoraceae (only the latter is still excluded from the Araceae). Nakai's students, Fumio Maekawa and Hiroshi Hara, were also very much interested in Araceae, especially *Arisaema*. Maekawa (1924, 1932, 1934, 1936, 1937) described new species from Japan. Hara described new species of *Arisaema* (Hara, 1935a, 1935b, 1961, 1965; Hara & Ohashi, 1973) and made critical revisions for the *Flora of the Eastern Himalaya* (Hara, 1966, 1971a). Later he proposed an infrageneric system of classification for the genus *Arisaema* (Hara, 1971b), a system since adopted by Wu Cheng Yih and Li Heng (1979) and recently revised by Jin Murata (1984). A later paper described additional species from Himalaya (Hara, 1973).

Another Japanese botanist, Shiro Kitamura, working about the same time as Hara, published several significant papers on Araceae of Japan (Kitamura, 1941,

1949; and compiled *Coloured Illustrations of Herbaceous Plants of Japan* (Kitamura *et al.*, 1977) that contains line drawings and paintings of Araceae.

## AFRICA

Most floristic projects on the continent were initiated by the colonial powers, including Belgium and Germany, and especially Britain and France. In general, the Araceae treatments were completed by botanists who were competent researchers but not formally trained aroid specialists. One such botanist was F. N. Hepper, who contributed the Araceae treatment for the *Flora of West Tropical Africa* (Hepper, 1968a-c). Hepper's treatment of the Araceae for that flora [a revision of an earlier flora by the same name (Hutchinson & Dalziel, 1936)] is a remarkably good one. His understanding of the genus *Culcasia* (Hepper, 1965, 1967), probably the most complex genus in Africa, was particularly good. An exception to the rule that most flora writers were non-aroid specialists might be N. E. Brown who prepared the Araceae treatment for the *Flora of Tropical Africa* (Brown, 1901). Other publications that contributed to the generally high level of knowledge about African flora include some generic studies for the entire continent (Thonner, 1915), South Africa (Dyer, 1976), and Central Africa (Bamps, 1982; Malaisse & Bamps, 1993). Other publications include general floristic studies in the Mascarene Islands (Mayo, 1983b), German East Africa (or Tanganyika and now mostly Tanzania) (Mildbraed, 1936; Peter, 1929), Belgian Congo (Katanga) [until recently Zaire and now Congo] (Wildeman, 1921, 1922), Senegal (Lykke, 1994), as well as Egypt and western Asia (Boisser, 1884) and Ghana (Beath, 1993). Papers focusing mainly on African species include those on *Zantedeschia* (Letty, 1973; Perry, 1989), *Zamioculcas* (Obermeyer & Strey, 1969); *Stylochaeton* (Malaisse & Bamps, 1994); *Remusatia* (Robyns, 1931), *Gonatopus* (Obermeyer 1977; Obermeyer & Bogner, 1979), and *Amorphophallus* (Ittenbach, 2003). A recent paper enumerates species of Araceae in 30 genera (including introduced genera) from tropical West Africa (Lebrun & Stork, 1995). [See also Ntépe-Nyame and Knecht, below.]

Madagascar was a special interest of Samuel Buchet (Bogner, 1980g), a French botanist who described *Arisaema* and *Pothos* species from Asia (Buchet, 1911a, 1911b) and studied the Arophyteae (Buchet, 1939a, 1942), the dominant element of the Malagasy flora. Josef Bogner (see below) has had the greatest impact on the study of Araceae in Madagascar. The Seychelles near Madagascar also has an interesting flora and the island is important as having the endemic

genus *Protarum* (Robertson, 1989).

## AMERICA

In contrast to Africa and Asia where there were strong botanical interests within the colonial powers, the neotropics had little early exploration and very few floristic projects. Neither Spain nor Portugal made much headway towards the production of floras nor did they even launch major collecting programs. Exceptions were the expeditions of Sesse & Moçino, Ruiz & Pavon, and Triana & Planchon, but they collected few specimens of Araceae.

Regardless of their origin, most 18th and 19th Century botanists collected and described relatively few Araceae, though some are worthy of mention. E. F. Poeppig collected and described a number of important species of Araceae from Peru and Brazil (Poeppig, 1845). Also important was A. F. M. Glaziou and H. W. Schott, both working in Brazil. While Glaziou collected many species described by Schott and others he did not publish any species himself. F. A. W. Miquel collected important Araceae in the Guianas, as did R. Spruce in the Amazon basin (though the latter did not publish any new species). Aside from Luis Sodiro, who collected Araceae in Ecuador [see Sodiro above], most of the other important collectors of Araceae in the 19th Century did not publish on Araceae. These included F. Lehmann, collecting in the western Andes of Colombia and Ecuador, E. Ule in the upper Amazon basin, as well as August Fendler and H. Pittier collecting in Venezuela.

With the notable exception of J. M. da Conceição Vellozo (1742-1811) who published Araceae in his *Flora Fluminensis* (Vellozo, 1825(1829), 1831a, 1831b) few early Portuguese or Spanish described Araceae [see Stellfeld, 1950 for an account of the work of Vellozo]. With the minor exceptions of M. S. Bertoni (Paraguay), G. M. Barroso, specializing on Araceae at the Rio de Janeiro Botanical Garden, and P. R. Reitz, also from Brazil and working on the *Aráceas Catarinensis* (Reitz, 1957), few Araceae were described by native-born Latin Americans. In Latin America as in Asia, the new species were in part described by the flora writers from other countries or by plant explorers such as Europeans N. J. Jacquin, F. A. W. Miquel, and others. The works of Jacquin (1760, 1763, 1772, 1790a, 1790b, 1797) based on his travels in the West Indies are important because he was one of the first to describe Araceae from the New World. His colored paintings in *Icones Plantarum Rariorum* (Jacquin, 1790a) are particularly

noteworthy. John G. Baker described and illustrated a number of Araceae, especially *Anthurium* in Saunder's *Refugium Botanicum* (Baker, 1871). S. L. Moore included Araceae in his studies of the plants of Mato Grosso in Brazil (Moore, 1895).

During the 20th Century, American institutions began serious studies in Latin America and authors such as P. C. Standley, who wrote a series of floras in Central America, and J. F. Macbride, who worked on the *Flora of Peru*, described a number of new species. In addition, small but important collections were described from Colombia by R. E. Schultes during his ethnobotanical studies of the neotropics and L. Diels (1937a, 1937b), working at the Berlin Botanical Garden, described collections made in Ecuador. The Dutch under Pulle also started a flora in Suriname, then a Dutch territory. Floristic studies did not play as great a role in the Americas as they did in Asia and Africa; however, a number were done. For South America these include: Argentina (Crisci, 1971; Crisci & Katinas, 1999; Hauman & Vanderveken, 1917); Buenos Aires Province (Crisci, 1968a); Bolivia (Rusby, 1910, 1927); Brazil (Engler in Martius, 1878a; Stellfeld, 1950), Amazonas (Smith, 1939), Bahía (Harley & Mayo, 1980); Rio Grande do Sul State (Rambo, 1950), Rio de Janeiro State (Casiri, 1982); Cardoso Island (Olaio & Catharino, 1991); Colombia (Garcia-Barriga, 1974; Escobar, 2001; Forero & Gentry, 1989; Gines *et al.*, 1953; Galeano & Bernal, 1993); Ecuador (Dodson & Gentry, 1978; Dodson *et al.*, 1985); French Guiana (Aublet, 1775; Lemée, 1955; Croat, 1995b); Guyana (British Guiana) (Gleason, 1929; Graham, 1934); Paraguay (Bertoni, 1916; Chodat & Hassler, 1903; Chodat & Vischer, 1919; Croat & Mount, 1988); Peru (Macbride, 1936); Surinam [see Jonker-Verhoef & Jonker below]; Uruguay (Herter, 1943; Marchesi, 1984); and Venezuela (Pittier *et al.*, 1945; Maguire, 1948; Steyermark, 1951; Steyermark & Huber, 1978; Bunting, 1995; Gines *et al.*, 1953).

The earliest effort to produce a flora from Central America was that by William Botting Hemsley (Hemsley, 1885a). Other floristic works done later include those by: L. O. Williams (1981) in Central America; I. Johnston (1949), F. Liebmann (1849), C. L. Lundell (1937, 1939, 1941), R. McVaugh (1993), M. Martínez & E. Matuda (1979), and Espejo Serna & Lopez Ferrari (1993) in Mexico; McVaugh (1993) and Vásquez *et al.* (1995) in western Mexico; H. H. Bartlett (1937) in Petén Province, Guatemala; T. K. Yuncker (1940) and A. Molina (1975) in Honduras; D. L. Spellman *et al.*, (1975) in Belize; Engler (1900) in Costa Rica, and Paul Standley (see Standley below) in various other



countries.

In the West Indies, floristic studies have been numerous and this area was one of the first to be explored by collectors such as C. Plumier, H. Sloane, N. J. Jacquin, and others. In fact, many of the earliest names of New World plants are based on West Indian types. General floristic accounts include: the Dutch Antilles (Arnoldo, 1971; Boldingh, 1913); Jamaica (Adams, 1972; Proctor, 1982); Cayman Islands (Proctor, 1984); Cuba (Grisebach, 1864, 1866; Sauvelle, 1868; Leon, 1946); Haiti (Barker & Dardeau, 1930; Liogier, 1981); Dominican Republic (Moscoso, 1943; Hodge, 1954a); Puerto Rico (Liogier, 1965; Liogier & Martorell, 1982); Puerto Rico and the Virgin Islands (Britton & Wilson, 1923, 1926; Acevedo-Rodríguez, 1966); the Windward and the Leeward Islands (Beard, 1949); Barbados (Gooding *et al.*, 1965); Guadeloupe and Martinique (Heckel, 1897); and Lesser Antilles (Howard, 1979).

#### 1920–1950: A DERTH OF ARACEAE RESEARCH

Only a few of the earlier above mentioned non-specialists and flora writers did specialized research with Araceae during the three decades following the completion of Engler's treatment of the family in *Das Pflanzenreich* (Engler, 1905a, 1911, 1912, 1915, 1920a-c). A few floristic projects in the neotropics were pursued, such as the Araceae treatment for the *Flora of Peru* (Macbride, 1936) and various floristic projects by Paul Standley in Central America. Perhaps the lack of monographic research was due to the disruption caused by two World Wars and a major worldwide depression, or to the mistaken belief that the *Das Pflanzenreich* treatment was a complete revision of all the species that existed. However, there are exceptions to this ebb in specialized research activity during the 1920s through the 1940s. For example, there was research with leaf architecture by the German botanist P. Ottmar Ertl (1932). This work detailed petiolar anatomy, blade shape, and included an analysis of venation in many different genera of Araceae. Other general publications dealt with chromosomes in *Anthurium* by Lulu O. Gaiser (Gaiser, 1927, 1930) and other miscellaneous genera (Jussen, 1928; Ito, 1942).

The French botanist, Samuel Buchet, published several papers dealing with the systematics of the Araceae between 1920 and 1939 (Buchet, 1939a, 1939b, 1942; Buchet & Guillaumin, 1939). He published new plant species descriptions from Asia and especially from Madagascar. Another Frenchman, H. Jumelle, also

worked on the plants of Madagascar (Jumelle, 1919, 1928). Still another French botanist, A. Chevalier, published a few papers on Araceae during the same era. These dealt with aquarium plants, *Cryptocoryne* (Chevalier, 1934a, 1934b), and *Cercestis* in West Africa (Chevalier, 1920). In the late 1940s and early 1950s the Indian botanist, D. Chatterjee, published new species of *Arisaema* from Burma, India, and Sikkim (Chatterjee, 1949, 1955).

## **MATUDA**

Although botany languished to some extent in other parts of the world due to the influence of World War II, there was a renewed interest in research in the Western Hemisphere after the war. The first signs of renewed research activity was with the Araceae in Mexico. Eizi Matuda, a native of Nagasaki, Japan but a naturalized Mexican citizen since 1928 (arriving in 1922), worked extensively on Araceae in the 1950s. Matuda was a field man and traveled into remote areas by mule, thus acquiring an excellent knowledge of much of tropical Mexico. His descriptions, though relatively detailed, do not compare with those of Sodiro. Matuda's first papers published a new species of *Dracontium* (Matuda, 1949) as well as one of *Monstera* and *Philodendron* (Matuda, 1949a). These were followed by floristic accounts of particular regions including Mount Ovando (Matuda, 1950a), the districts of Soconusco and Mariscal (Matuda, 1950b), and the state of Mexico (Matuda, 1957a). Miscellaneous new Mexican species were described in nearly all Mexican genera of Araceae throughout his career (Matuda, 1950c, 1950d, 1951, 1952, 1956a, 1956b, 1957b, 1959a, 1959b, 1961a, 1961b, 1965, 1966, 1972, 1975). In all, Matuda described more than 50 species of Araceae, all from Mexico. His most useful work is a treatment of the Araceae of Mexico, which includes both dichotomous keys and descriptions (Matuda, 1954).

## **FLORISTIC WORK IN SOUTH AMERICA**

During the time that Matuda was collecting and describing plants in Mexico, Richard Evans Schultes, a non-aroid specialist, was collecting and describing new species in conjunction with his ethnobotanical studies in South America, especially Amazonian Colombia. His ethnobotanical findings are summarized in a book (Schultes & Raffauf, 1990). In all, Schultes described about 20 species. Many of these remain accepted names (Schultes, 1953, 1954, 1958, 1959, 1963, 1964a, 1964b; Schultes *et al.*, 1978, 1994).

At about the same time, Basset Maguire from the New York Botanical Garden discovered new species during his expeditions to the Guayana Highlands (Maguire, 1948). Among those participating in his expeditions were George Bunting and Julian Steyermark. Some new species were named independently by Steyermark or Bunting, but some were also described by Alex D. Hawkes, a Californian. Though some of the species that Hawkes described proved to be new, he frequently placed species in the wrong genus. Though Hawkes described species in several papers (Hawkes, 1948, 1951a, 1951b) he was not really considered an expert on aroids.

Research with Araceae also was renewed in South America during the 1950s with the *Flora of Suriname* project. This work was carried out during the 1950s and mid-1960s by A. M. E. Jonker-Verhoef and her husband F. P. Jonker. The first paper in the series (Jonker-Verhoef & Jonker, 1953a) updated Pulle's 1906 *Enumeration of the Vascular Plants of Surinam* and described two new species. Later in the same year, a new treatment of the Araceae of Suriname (Jonker-Verhoef & Jonker, 1953b) was published treating 18 genera and 67 species. As a sign that most tropical floras started toward the middle of the present century were begun prematurely, a paper published only six years later added another thirteen species new to the flora (Jonker-Verhoef & Jonker, 1959) and yet most others (Jonker-Verhoef & Jonker, 1966, 1968) report an additional 7 species. The work done by the Jonkers was thorough and detailed, but their interest with the Araceae did not extend beyond Suriname.

## **FLORISTIC WORK IN CENTRAL AMERICA**

Paul C. Standley was more of an aroid specialist since he did Araceae treatments for a half dozen separate Central American flora or florulas that described new Araceae during the decades of the 1930s and 1940s. These floras were for the Panama Canal Zone (Standley, 1928), Lancetilla Valley in Honduras (Standley, 1931), Barro Colorado Island (Standley, 1927, 1933), Belize (Standley & Record, 1936), Costa Rica (Standley, 1937), Panama (Standley, 1944), and Guatemala (Standley & Steyermark, 1958). In addition, he published several other smaller papers with new species descriptions (Standley, 1932, 1940a, 1940b, 1944, 1958b; Standley & Steyermark, 1943; Standley & L. O. Williams, 1951; 1952). Still, considering how many potential new species there were in Central America, Standley and his coworkers did not describe very many. In all, Standley alone or with Julian Steyermark and/or Louis O. Williams described 42 species of

Araceae during this era.

## RENEWED REVISIONARY EFFORTS AFTER 1950

In addition to the floristic efforts that began in the early 1950's, considerable new revisionary activity began with a number of new aroid researchers. One of first of these was H. C. D. de Wit who worked exclusively with the limited number of aquatic aroids that can be grown in fish tanks. These plants have a good commercial value and have spawned a number of research projects, most of them centered at the University of Wageningen in Holland and in other places in Europe. The most active research on these aquatic aroids began with de Wit and Karel Rataj and progressed until the time that Niels Jacobsen published several important papers on the genus *Cryptocoryne* [see below]. New species continue to be discovered in the genus.

De Wit published his first papers, all dealing with *Cryptocoryne* in 1953 (de Wit, 1953a-c). They were published in popular aquarium magazines *Fishkeeping and Waterlife* and *Het Aquarium*. Other species of *Cryptocoryne* were treated in papers published in succeeding years (de Wit, 1954, 1956, 1957, 1958a-g), and it was not until 1958 that de Wit described his first new species (de Wit, 1958b). He then published many short papers (de Wit, 1959a-i; 1960a-e, 1961a-e, 1963a-d, 1971a-c, 1975a, 1975b, 1976, 1979) in *Het Aquarium* a Dutch magazine popular with the aquarium enthusiasts. Written in Dutch and of one to four pages in length, each article deals with a single species of *Cryptocoryne*. Each fascicle is illustrated with photographs or detailed drawings and sometimes with colored paintings or photographs. One additional species was described in *Artemis* (de Wit, 1975b). The first widely useful paper by de Wit presented a key to all the known species of *Cryptocoryne* along with detailed photographs (de Wit, 1969).

De Wit's other publications include a short article on pollination in *Cryptocoryne* (de Wit, 1978a), chromosome numbers (de Wit & Jacobsen, 1982), and a complete revision of another aquatic genus, *Lagenandra* Dalzell (de Wit, 1978b). The publication is written in Dutch and contains excellent illustrations and keys as well as details on the biology. De Wit has summarized his work nicely in a series of books, all well illustrated with detailed drawings and colored plates. These books deal with numerous aquatics but the Araceae constitute the largest share (de Wit, 1983). The first version was printed in Dutch (de Wit, 1966), reprinted in 1982 (de Wit, 1982), and an essentially identical version was

published in 1990 in German (de Wit, 1990).

Simultaneously, the Czech botanist, Karel Rataj was doing revisionary work on *Cryptocoryne*. His book on *Cryptocoryne* (Rataj, 1975) divided the genus into 4 subgenera and 16 sections and described three of the subgenera and all of the sections as new. Rataj recognized 52 species of *Cryptocoryne* while describing seven new species and six new varieties. Another paper described new cultivated species of the genus (Rataj, 1974). Rataj also published a book *Aquarium Plants*, which he coauthored with T. Horeman (Rataj & Horeman, 1977) as well as a paper dealing with *Typhonium flagelliforme* (Rataj, 1982).

In the 1950s, Haruyuki Kamemoto, working at the University of Hawaii, carried out an extensive breeding program with *Anthurium* in order to provide new and beautiful stock for the Hawaiian cut flower industry. Much of his original stock of wild collected material came from a field trip to Panama with Yoneo Sagawa in the early 1960s. Kamemoto's successes were many and most of his publications dealt with the development of new cultivars (Kamemoto & Nakasone, 1955, 1963; Kamemoto & Sheffer, 1978, 1982; Kamemoto *et al.*, 1986, 1993). He also did genetic research with Araceae, especially the inheritance of color in the spathe, in collaboration with R. Y. Iwata, C. S. Tang, S. Wannakraioj and M. Marutani (Iwata *et al.*, 1985; Marutani *et al.*, 1987; Kamemoto *et al.*, 1988; Wannakraioj & Kamemoto, 1990a, 1990b). Other technical research done by Kamemoto and his students include the use of gel electrophoresis for the identification of *Anthurium* cultivars (Kobayashi *et al.*, 1987) and an extensive use of cytology, especially by R. Sheffer, S. Wannakraioj, K. Kaneko (Kaneko & Kamemoto, 1978), and M. Marutani (Marutani *et al.*, 1988, 1993) [see also Sheffer below].

Kamemoto's many years of research with aroids are summarized in a book entitled *Breeding Anthurium in Hawaii* (Kamemoto & Kuehnle, 1996), coauthored by Adelheid R. Kuehnle [see Kuehnle below] who took Kamemoto's position at the University of Hawaii upon his retirement.

A small group of researchers in the Department of Horticulture at the University of Hawaii continues the *Anthurium* studies begun by H. Kamemoto. Most of the work, carried out with students under the supervision of Adelheid R. Kuehnle or in collaboration with her colleagues, Tessie Amore and Nellie Sugii (the latter two, who deal with classical plant breeding and histology), histologist

David Webb and biochemist T. S. Tang, deals with aspects of plant cultivation (Kuehnle *et al.*, 1996), breeding, morphology, embryology (Kuehnle *et al.*, 1996), novel methods of regeneration (Kuehnle *et al.*, 1992; Kuehnle & Sugii, 1991a, 1991b) and gene transfer (Kuehnle & Chen, 1994; Chen & Kuehnle, 1996; Kuehnle & Nan, 1991). Tracie K. Matsumoto, a student of Kuehnle, did her thesis on the embryology of *Anthurium* (Matsumoto, 1994) and has subsequently published other papers on the origin of somatic embryos (Matsumoto *et al.*, 1996) and on improvements of observing plant structures with light microscopy (Matsumoto *et al.*, 1995), and on micropropagation of *Anthuriums* (Matsumoto & Kuehnle, 1966). Nuttha Kuanprasert, another student, has begun a study of *Anthurium* fragrances (Kuanprasert & Kuehnle, 1995).

Monroe Birdsey, who did his graduate work at the University of California then taught at Miami-Dade Community College in Miami, was active in the Araceae with research during the 1950s. His unpublished thesis, entitled *The morphology and taxonomy of the genus Syngonium Schott* (Birdsey, 1955a), was a thorough study with emphasis on anatomy. Always interested in cultivated plants, he published *The Cultivated Aroids*, one of the earliest popular books of its kind devoted to Araceae (Birdsey, 1951). This work illustrated and described 70 species of Araceae. Shorter works include articles placing *Pseudohomalomena pastoensis* into synonymy with *Zantedeschia aethiopica* (Birdsey, 1955b), taxonomic problems with the confusing cultivar "golden pothos" (*Epipremnum pinnatum* cv. *aureum*) (Birdsey, 1962b), and the reintroduction of *Homalomena roezlii* (Birdsey, 1962a) into cultivation. His collection of living plants at his estate in Miami was until his death one of the finest of its kind in the world, possessing many fully-grown species of Araceae.

Donald G. Huttleston, who revised *Arisaema* of North America, published a discussion of three subspecies of *Arisaema* (Huttleston, 1949) even before he completed his thesis. His thesis involved a taxonomic study of the Araceae of North America (Huttleston, 1953). Other papers dealt with the nomenclature of *Lysichiton* (Huttleston, 1955) and further reports on *Arisaema* (Huttleston, 1981, 1984).

B. Bergdolt (1955), working at Freiburg University in Germany, worked with anatomical and embryological research on leaf mottling and other leaf types.

Finally, in the late 1950s and early 1960s, the Dutch botanist, R. C.

Bakhuizen v.d. Brink, though never deemed to be a major player in Araceae, did make significant contributions with his studies of the Araceae of Java (Bakhuizen, 1957; Bakhuizen & Koster, 1963). He also published a paper dealing with the differences in certain members of the Monsteroideae (Bakhuizen, 1958).

Despite the scattered and localized research mentioned earlier it was not until the beginning of the 1960s that much serious research with Araceae re-occurred since the time of Engler and Krause. The early 1960s saw the active publication by taxonomists George S. Bunting, Graziela Maciel Barroso, Dan Nicolson, Mitsuru Hotta, Cecil T. Prime, Harald Riedl, and Hiroyoshi Ohashi. Though Bunting's publication career was strongest during the 1960s, his first paper, a key to the genera of Araceae in Venezuela written in Spanish, was published in the mid-1950s (Bunting, 1956). Articles regarding cultivated aroids came next (Bunting, 1955, 1956b, 1959, 1961b) followed by the publication of his Ph.D. thesis, a revision of the genus *Spathiphyllum* Schott (Bunting, 1960a) and a continued flurry of publications throughout the 1960s, many of which dealt with mostly Venezuelan genera (Bunting, 1960b; Bunting & Steyermark, 1969) or floristic regions in Venezuela such as Chimantá (Bunting, 1963a) or Auyán-tepuí (Bunting, 1967) and the Sierra de Lema (Bunting, 1963b), the description of new species (Bunting, 1963c) or taxonomic problems with cultivated plants including *Spathiphyllum* (Bunting, 1961a), *Dieffenbachia* (Bunting, 1962a, 1963d, 1966a, 1988c), *Alocasia* (Bunting & Nicolson, 1963), *Anthurium* (Bunting, 1963d), *Monstera* (Bunting, 1962d, 1966a, 1966b), *Syngonium* (Bunting, 1966b), and *Philodendron* (Bunting, 1966d, 1966e; Moore, 1974). Other papers dealt with the differences between *Schizocasia* and *Alocasia* (Bunting, 1962b), the delimitation of genera of the Monsteroideae (Bunting, 1962c), and a discussion of *Philodendron hederaceum-scandens* complex (Bunting, 1963f). Of his papers treating species of areas other than Venezuela, the most useful are his commentary on the Araceae of Mexico (Bunting, 1965) and a discussion of the anatomy and taxonomy of the *Philodendron scandens* complex (Bunting, 1968).

Part of Bunting's early work began at the Missouri Botanical Gardens, and then continued at the Bailey Hortorium at Cornell University. From Cornell he moved to Venezuela where his extensive field studies and collections of Araceae formed the basis for a treatment of the Araceae for the Flora of Venezuela. Toward this end he has published many new species for Venezuela and adjacent countries (Bunting, 1975, 1986, 1987, 1988a, 1989a) and a new genus (Bunting, 1988b, 1989b) for Venezuela and adjacent countries. Though the Araceae

treatment for the Flora of Venezuela has not been finished, a major synopsis of the flora has been published (Bunting, 1979). It contains most of the species and taxonomic keys but no descriptions or illustrations. Bunting has also published a treatment of the Araceae for the flora of the Cerro Aracamuni in Venezuela (Bunting, 1989c) and the *Flora of the Venezuelan Guayana* (Bunting, 1995). Aside from his work with the flora of Venezuela, his principal interest for many years was a revision of the genus *Philodendron*. One of his major contributions has been with cultivated plants, a major emphasis in his earlier years. He contributed all the Araceae for *Hortus Third* (Bunting, 1976) and the *Philodendron* for the *European Garden Flora* (Bunting, 1984). Bunting has also described the genus *Jasarum* as well as many other species, 195 in all, mostly from Venezuela.

Graziela Maciel Barroso, working on Brazilian Araceae, made the description of *Philodendron camposportoanum* G. M. Barroso in her first publication (Barroso, 1956). This was followed by a series of papers describing other new species (Barroso, 1957, 1959, 1965, 1970). All but one, *Anthurium wendlingeri* G. M. Barroso from Costa Rica, represented Brazilian species. Barroso published 15 species in all.

Dan H. Nicolson, working at Cornell University, published extensively throughout the 1960s. His first publications on Araceae were a review of the classification of the Araceae (Nicolson, 1960a) and a paper describing the occurrence of trichosclereids in the Monsteroideae (Nicolson, 1960b). Several other papers, including one on *Gorgonidium* (Nicolson, 1963) and revisions of small groups, e.g. *Filarum* (Nicolson, 1966); *Xenophya* (Nicolson, 1968a); Asian *Spathiphyllum* (Nicolson, 1968b, 1992a); and *Amydrium* (Nicolson, 1968c) were published in part even before his Ph.D. thesis, a revision of the genus *Aglaonema* (Nicolson, 1967b, 1969). The work with *Aglaonema* involved extensive fieldwork in the Asian tropics that led to a continued interest in Asian floristic accounts including floristic accounts of the Araceae of the Hassan District (Nicolson, 1976a) and the Tamilnadu Carnatic regions (Sivadasan & Nicolson, 1983) of India, as well as for Fiji (Nicolson, 1978, 1979), and Sri Lanka (Ceylon) (Nicolson, 1988). Nicolson (1984f) also treated the *Aglaonema* for the *European Garden Flora*. With C. R. Suresh and K. S. Manilal in India he discussed H. A. van Rheede's *Hortus Indicus Malabaricus* [SW India] (Nicolson *et al.*, 1988). His interest in fieldwork also resulted in papers on collecting Araceae (Nicolson, 1965, 1976b).



Along with Josef Bogner, Nicolson has been involved with studies and revisions of the suprageneric system of classification (Bogner & Nicolson, 1991) resulting in one of the competing systems of classification of the Araceae. This was among the first to question the classification of Engler.

Early in his career Nicolson became interested in the legal matters of nomenclature (Nicolson, 1963b, 1964, 1967a, 1968d, 1975a, 1975b, 1977, 1981b, 1984b-d, 1987a; Nicolson & Bogner, 1977, 1981; Nicolson & Mayo, 1984a, 1984b; Nicolson *et al.*, 1984), an interest that continues to this day. He has spent much of his career dealing with nomenclature of Araceae and suprageneric systems of classifications (Bogner & Nicolson, 1991). Other work includes a survey of floral anatomy of Araceae carried out in conjunction with R. H. Eyde and P. Sherwin (Eyde *et al.*, 1967). In collaborative efforts he published papers on *Alocasia* (Bunting & Nicolson, 1963), a revision of *Gorgonidium* (Bogner & Nicolson, 1988), new species of *Arisaema* (Sivadasan & Nicolson, 1983) and *Theriophonum* (Sivadasan & Nicolson, 1981), a revision of *Typhonium* with M. Sivadasan (Nicolson & Sivadasan, 1981) as well as one on the taxonomy of *Theriophonum* (Nicolson & Sivadasan, 1982). One of his major accomplishments is his study of the complex publication history of Luis Sodiro (Nicolson, 1984a), who had the practice of publishing each new species several times. Until Nicolson's enlightening work, many of the earliest valid publications were overlooked. He also alphabetized and indexed Schott's *Icones Aroideae and Reliquae* (Nicolson, 1984e). Nicolson's translation of Engler's classification of the Araceae including the key to genera made understanding and ultimate revision of that system possible (Nicolson, 1982a). Nicolson is a member of the editorial board for both *Taxon* and *Aroideana* and has an interest in aroid literature (Nicolson, 1989, 1992b). His understanding of classical languages as well as German, the history of early aroid taxonomy (Nicolson, 1982a, 1987a), the rules of nomenclature, and his role as Senior Curator at the Smithsonian Institution where he has worked since he left Cornell make Nicolson the person to whom many of us turn for advice. His contributions to the Araceae are unique. In 1999 at the VIII International Aroid Conference in St. Louis Dan Nicolson was awarded the first H.W. Schott Award for Excellence in Aroid Research.

Harald Riedl, working at the Naturhistorisches Museum in Schott's hometown of Vienna, published his first paper on the Araceae in the *Flora Iranica* (Riedl, 1963). He is also a specialist on the genus *Eminium* (Riedl, 1969) and the

flora of Middle Europe and the Middle East, and has published on *Arum* (Riedl, 1967), and *Stylochiton* (Riedl, 1990) [the latter from Africa] as well as having written the Araceae treatment in Hegi's *Illustrierte Flora von Mitteleuropa* (Riedl, 1979) and the Araceae treatment in the *Flora of Iraq* (Riedl, 1985). Riedl is also an expert on the history of H. W. Schott and has published several papers dealing with Schott's work and collections (Riedl, 1965a-c, 1966, 1978; Riedl & Riedl-Dorn, 1988). He published several papers in the earliest issues of *Aroideana*, including a discussion of the aroids described in Russel's *Natural History of Aleppo* in 1794 (Riedl, 1980a), a partial treatment of *Biarum* Schott (Riedl, 1980b), and a paper stressing the importance of ecology in defining genera (Riedl, 1980c).

The earliest of these was Mitsuru Hotta, working at the Kyoto University in Japan, who began publishing papers on Araceae in 1963 (Hotta, 1963a, 1963b). Some of his first papers dealt with *Arisaema* of Japan (Hotta, 1963a, 1963b, 1964, 1966a, 1970a-d) but he soon began working in more tropical parts of Asia, including Borneo, where he studied the Schismatoglottidinae (Hotta, 1965, 1966b, 1987) and made phytogeographic and floristic surveys (Hotta, 1966c, 1967). His work in Borneo resulted in the description of two new genera, *Pedicellarum*, *Phymatarum*, and *Heteroaridarum* (Hotta, 1976). His work in Sumatra has resulted in floristic surveys (Hotta, 1984), another new genus, *Furtadoa* M. Hotta (Hotta, 1981), other miscellaneous new species (Hotta, 1985, 1993), a survey of *Homalomena* and *Anadendrum* of Sumatra (Hotta, 1986a, 1986b), and a paper on taro uses (Hotta, 1962, 1983). Hotta (1982) also made detailed comparisons of the Homalomeninae and the Schismatoglottidinae in Malesia.

One of Hotta's major accomplishments was a system of classification in which he proposed major first-time changes in the suprageneric system of classification of the Araceae (Hotta, 1970a). His system of classification is discussed in detail and is compared with other major systems (Croat, 1990). Another major publication (Hotta, 1971) provided a detailed discussion of the relationship of the Araceae to other families and discusses the morphological, anatomical, and cytological characteristics of different aroid subfamilies. In recent years, Hotta has been involved (sometimes with Hiroshi Okada and Motomi Ito) in ecological studies with Araceae in West Sumatra (Okada, 1986; Hotta *et al.*, 1985; Okada & Hotta, 1987). His skills in cytology, broad ranging ecological interests and astute observations have made Hotta's contributions to Southeast Asian studies of Araceae diverse, unique, and important.

Hiroyoshi Ohashi, at the University of Tokyo and Tohoku University, began publishing on Japanese *Arisaema* in the early 1960s. Miscellaneous notes on *Arisaema* (Ohashi, 1963, 1964) were followed by a complete revision of the genus for Japan (Ohashi & J. Murata, 1980), and the Araceae treatment for the *Wildflowers of Japan* (Ohashi, 1982). Continuing the work of Hara on the *Flora of Eastern Himalaya*, Ohashi published a third report of that work which included additional *Arisaema* (Ohashi, 1975). Ohashi also compiled a list of types of *Arisaema* in Japanese herbaria (Ohashi, 1981a, 1981b) and studied pollen morphology of Japanese *Arisaema* (Ohashi *et al.*, 1983). A recent paper describes a new species of *Piptospatha* that regularly produces adventitious bulbils along the midrib on the lower blade surface (Ohashi *et al.*, in press).

A European specialist in *Arum*, Cecil T. Prime, was also active during the 1960s. His major work on the biology of *Arum maculatum*, *Lords and Ladies* (Prime, 1960), is one of the most detailed and interesting books ever written on the biology of an aroid. Prime also contributed the *Arum* section for the *Flora Europaea* (Amaral Franco *et al.*, 1980).

Although the taxonomists noted above were the main players within Araceae research, several post-Englerian non-specialists made significant or unique studies in specific areas of aroid research. Three individuals working with *Zantedeschia* are worthy of mention. Hamilton Traub produced a single work on *Zantedeschia* that has been one of the most useful ever done for that genus (Traub, 1949). The second work, published in the same year, was written by L. Mirzwick (Mirzwick, 1949). Most recently, Cynthia Letty (1973) also published a revision on *Zantedeschia*. Another work carried out by non-specialists was a minor revision of *Arisaema* by Walter Robyns and R. Tournay (Robyns & Tournay, 1955). This work treated five species of *Arisaema* from tropical Africa. Another useful work on *Arisaema* deals with the plants of the Himalayas (Pradhan, 1986, 1990).

With the advent of Bunting and Nicolson, interest in Araceae accelerated with several new workers, including: Josef Bogner, Tom Croat, Dorothy Shaw, Jorge Crisci, Mike Madison, Li Heng, Marija Bedalov, Richard Sheffer, Simon Mayo, and Jin Murata beginning their publishing careers with Araceae, in the late 1960s and 1970s.

Probably no one in the history of work with the family has had a greater

focus on research with Araceae than Josef Bogner. His unprecedented interest in the family is so universal that it is difficult to define. Beginning with a paper dealing with *Therophonum* (Bogner, 1968), Bogner has been involved with the Araceae in nearly all parts of the world, including a major study of the Araceae of Madagascar, the Comoros Islands, and with the Arophyteae (Bogner, 1972a, 1972b, 1973a, 1973b, 1975), as well as the Seychelles with *Protarum* (Bogner, 1973a, 1973e); and in Africa with *Amorphophallus* (Barthlott & Bogner, 1981; Bogner & Hetterscheid, 1992; Bogner, 2003); *Andromycia* (Bogner, 1969b); *Callopsis* (Bogner, 1969a [= *Nephtytis hallaei* (Bogner) Bogner, see Bogner, 1980b]); *Cercestis* (Bogner & Knecht, 1994); *Culcasia* (Bogner, 1980a); *Gonatopus* (Obermeyer & Bogner, 1979); *Nephtytis* (Bogner, 1980b; de Namur & Bogner, 1994); *Pseudohydrosme* (Bogner, 1981a); *Stylochiton* (Bogner, 1984f); in Asia with *Amorphophallus* (Bogner, 1976d, 1981a, 1981b, 1989a, 1995; Bogner *et al.*, 1985; Bogner & Hetterscheid, 1992); *Aridarum* (Bogner, 1979, 1981c, 1983a); *Cryptocoryne* (Bogner, 1974, 1984a-c, 1984i, 1985a, 1989c, 2004; Bogner & Jacobsen, 1985, 1986, Ehrenberg & Bogner, 1992); Jacobsen, 2002; Jacobsen, Bastmeijer & Sasaki, 2002; Sasaki, 2002); *Pycnospatha* (Bogner, 1973b); *Lagenandra* (Bogner, 1974, 1978; Bogner & Jacobsen, 1987); *Homalomena* (Bogner, 1976a); *Thomsonia* (Bogner, 1976b); *Bucephalandra* (Bogner, 1980c, 1984g); *Plesmonium* Schott (Bogner, 1980d), *Hottarum* (Bogner, 1983b, 1984g; Bogner & Hotta, 1983a); *Schismatoglottis* (Bogner & Hotta, 1983b; Bogner, 1988; Bogner & Hay, 2000); *Hapaline* and *Phymatarum* (Bogner, 1984e); *Scindapsus* (Bogner & Boyce, 1994); and *Typhonium* (Bogner, 1987a), as well as in the Americas with *Xanthosoma* (Bogner, 1986a); *Mangonia* (Bogner, 1973d, 2000); *Scaphispatha* (Bogner, 1980e); *Jasarum* (Bogner, 1977, 1984d, 1985d); *Dracontium* (Bogner, 1981d), *Caladium* (Bogner, 1980f, 1984h), *Chlorospatha* (Bogner, 1985b, 1985e), *Gearum* (1999), *Homalomena* (Bogner & Moffler, 1985a, 1985b), *Taccarum* (1989b); *Philodendron* (Bogner & Bunting, 1983), *Gorgonidium* (Bogner & Nicolson, 1988, *Gorgonidium* and *Anthurium* (Bogner & Gonçalves, 2002) and in Turkey with *Biarum* (Bogner & Boyce, 1989). With James French he described the tribe Anadendreae (Bogner & French, 1984). A recent paper (Bogner, 1997) described species from both the Old and New World (*Spathanthemum intermedium*, *Asterostigma cryptostylum*, *Zomicarpella amazonica*, *Ulearum sagittatum* var. *viridispadix* and *Nephtytis afzelii* var. *graboensis*). He has described a total of 56 new species. Josef Bogner has 6 specific epithets of Araceae named in his honor, and one genus, *Bognera*. He has been author or co-author of 2 subfamilies, one subtribe, two tribes, and 94 species of Araceae.

Bogner, because of his broad interests and deep understanding of all matters regarding Araceae, has long been principally interested at the subfamilial and tribal levels. He has been responsible for a rethinking of the system of classification of the Araceae beginning with his "critical list" of aroid genera (Bogner, 1978), the reduction of genera (Bogner, 1985c), new name and combinations (Bogner, 1986b), the placement of *Jasarum* (Bogner, 1980e), and his revised classification of the family (Bogner & Nicolson, 1991). A recent paper (Mayo *et al.*, in press) defining the relationship of the Araceae to other closely related families reflects his deep understanding of the family. He is a coauthor of *The Genera of Araceae* (Mayo *et al.*, 1997) that describes and illustrates all the genera of Araceae. Another summary paper by Bogner deals with the wide variation in morphology of Araceae (Bogner, 1987b), and another is on new taxa of Araceae (Bogner, 1997). Bogner is also one of the few aroid researchers who has dealt with fossil Araceae (Bogner, 1976c; Gregor & Bogner, 1984, 1989) and, along with Michael Hesse and other collaborators, has also published a review of the palynology of the perigonate members of the Aroideae (Hesse *et al.*, 2001). He is a member of the team doing the Flora Malesiana and is a coauthor of a checklist and bibliography of the region (Hay *et al.*, 1995a, 1995b) and has written about a collecting trip to Sarawak (Bogner & Boyce, 1995).

Last but not least are Bogner's capabilities as a grower, where few are his equal. His collection of living aroid genera, housed at the Munich Botanical Garden, is unparalleled. His many field trips to three continents where he successfully sleuths yet another poorly known genus or species are largely financed with his personal funds and his accumulated vacation time. This largely unrewarded effort on the part of Josef Bogner is one of the greatest contributions ever to the field of aroid research. In 1999 at the VIII International Aroid Conference in St. Louis he was awarded the first Bette Waterbury Award for Excellence in Horticulture.

One of the few South American botanists who played a role in research with Araceae is Jorge Crisci from the Museo de la Plata in La Plata, Argentina. His first paper dealing with Araceae was a treatment of the Araceae for the Flora of Buenos Aires Province (Crisci, 1968a). He then described new additions to the flora (Crisci, 1968b; Crisci *et al.*, 1991) or new species (Crisci, 1970). Most of his work involves floristic accounts of Argentina (Crisci, 1971; Crisci & Katinas, 1999). Finally, he wrote a systematic and ethnobotanical study of *Philodendron*

*bipinnatifidum* (Schott) Schott (Crisci & Gancedo, 1971).

Tom Croat, of the Missouri Botanical Garden, became interested in the Araceae in 1967 when, in conjunction with his work on the Flora of Barro Colorado Island (Croat, 1978a), he found the family to be the most difficult in the flora. Perplexed by the immense variation in species and the confusion of juvenile, preadult, and adult forms, he collected elsewhere in Panama where the wet forests were much richer and replete with undescribed species. Plants were collected and grown at Summit Gardens in the Canal Area, near where he lived, and later were transported to the Missouri Botanical Garden in St. Louis. His earliest paper on Araceae described a *Dracontium* from Barro Colorado Island (Croat, 1975a), followed later that year by a discussion of the *Anthurium gracile* (Rudge) Schott-*A. friedrichsthali* Schott complex of Central and South America (Croat, 1975b).

Croat's earliest interest was involved with the Araceae of Panama, the richest part of Central America (Croat, 1985a), and this led to floristic work with *Anthurium* in Central America sponsored by the National Geographic Society (Croat, 1977). This was followed by descriptions of new species of *Anthurium* (Croat, 1978c, 1979a, 1981a, 1983a), a concern for the standardization of species descriptions of *Anthurium* (Croat & Bunting, 1979), a revision of Central American *Anthurium* section *Polyphyllum* Engl. (Croat & Baker, 1978), a treatment of *Anthurium* for Costa Rica (Croat & Baker, 1979), a revision of the Araceae of the La Selva Reserve in Costa Rica (Croat & Grayum, 1994), a study of the flowering behavior of *Anthurium* (Croat, 1980), a study of the sectional classification of *Anthurium* (Croat & Scheffer, 1983), and a review and analysis of chromosome information for *Anthurium* (Sheffer & Croat, 1983b). Additional publications during this time were a revision of *Syngonium* (Croat, 1981b) and a review of the distribution of Araceae worldwide (Croat, 1979b).

A National Science Foundation supported revision of *Anthurium* of Central America began in 1977 (Croat, 1983a, 1986a, 1986b) and was followed, between 1980 and 1986, by a revision of *Anthurium* sect. *Pachyneurium* Schott for the neotropics (Croat, 1991a). The resulting field work in South America brought other involvements including papers on the Araceae of Venezuela (Croat & Lambert, 1987), a treatment of the Araceae for the *Flora de Paraguay* (Croat & Mount, 1988), a checklist for the Flora of the Guianas (Croat, 1992c, 1997a), the treatment for the *Flora of Central French Guiana* (Croat, 1997c) and for the flora

of Nicaragua (Croat & Stiebel, in press), the checklist for the flora of Peru (Croat, 1993), and for Ecuador (Croat, 1999) as well as more specific floristic studies of Colombia and Ecuador. In Colombia, a National Geographic grant sponsored study involved a comparative study of lowland pluvial forest-wet forest transition at Bajo Calima (Valle) and an upland premontane wet forest at La Planada (Nariño) (Croat, 1992). This in turn has led to student involvement and (as yet unpublished) treatments of the aroid floras of both areas, for La Planada with Jeff Lake (Croat & Lake, in prep.) and for Bajo Calima with Dorothy Bay (Croat & Bay, in prep.). Similar floristic studies in Ecuador resulted in a comparison of six biological reserves in Ecuador (Croat, 1995b) and a study of *Anthurium* in the Reserva ENDESA (Croat & Rodríguez, 1995). Another effort in Ecuador, done in cooperation with Ralf Leimbeck in the Podocarpus National Park in southern Ecuador, involved the description of a new species in *Anthurium* section *Belolonchium* and a review of the *Anthurium oxybelium* complex of northwestern South America (Leimbeck & Croat, 2002). A collaborative project in Ecuador involved modeling distribution patterns of *Anthurium* in Ecuador using GIS data from Tropicos at the Missouri Botanical Garden. The project was a dissertation project by Homero Vargas (QCNE) at the University of Missouri- St. Louis (Vargas *et al.*, 2004) and done with the collaboration of Trisha Consiglio and Peter Jorgensen (MO).

Other efforts dealing with Araceae include review papers on the use of neotropical Araceae as medicinal plants (Croat, 1994a), the locality of neotropical aroid collections (Croat, 1988a), the ecology and life forms of Araceae (Croat, 1988b, 1989), a comparative survey of three modern systems of suprageneric systems of classification (Croat, 1990), and a history and status of systematic aroid research (1998). Smaller revisionary studies include the *Anthurium bredemeyeri* Schott complex in Venezuela (Croat, 1985e), a treatment of the Araceae entitled *In Gardens of Hawaii* (Croat, in press), a treatment of *Syngonium* (Croat, 1984a) and *Alocasia* for the European Garden Flora (Croat *et al.*, 1984).

Miscellaneous papers dealing with Araceae include historical briefs on aroid specialists including Matuda (Croat, 1978b) and Engler (Croat, 1983c), as well as reports on aroid conferences (Croat, 1985f, 1992b, 1994b; Croat & Cosgriff, 2000), discussions of collecting and preparation procedures for Araceae (Croat, 1985b, 1969), special drying facilities needed for Araceae collections (Croat, 1979d), labeling living collections (Croat, 1984d), germination of seeds (Croat, 1979c), and propagation of cuttings (Croat, 1981c). Other miscellaneous papers

deal with a discussion of *Anthurium andraeanum* Linden (Sheffer *et al.*, 1980), *A. leuconeurum* Lem. (Croat, 1983d), the description of new South American species (Croat, 1987, 2001; Croat & Finch, 2002[2003]; 2004; Croat, Mayo & Boos, 2002[2003]; Croat & Cornejo, 2004; Croat & Oberle, 2004; Mora & Croat, 2004; Croat & Langan (in press); Langan & Croat (in press); (Croat, Langan & Davila, in press); Croat, Langan & Hayworth (in press); reports on living collections of Araceae (Croat, 1979d, 1988c) or of field trips (Croat, 1982a, 1982b, 1991b), reports on rare (Croat, 1983b, 1984b, 1985c, 1995a) or poorly known species (Croat, in prep.), new combinations (Croat & Grayum, 1987, 1994), new records (Croat & Pérez-Farrera, 2000), a new species of *Philodendron* subgen. *Meconostigma* (Croat, Mayo & Boos, 2002), a description of a new species of *Ulearum* (Croat & Feuerstein, 2002) and illustrative profiles of aroids, including *Philodendron rugosum* Bogner & G. S. Bunting (Croat, 1984c), *Taccarum weddellianum* Brongn. ex Schott (Croat, 1985d), and *Syngonium steyermarkii* Croat (Croat & Bogner, 1987). With Kay Rossmann, he produced an index for the first ten volumes of *Aroideana* (Croat & Rossmann, 1991). A collaborative project conducted with the help of Anne Swart and Emily Yates resulted in a treatment of the Araceae of the Flora of the Río Cenepa Region by Rodolfo Vásquez (Croat, Swart & Yates, in press). This resulted in a paper describing 47 new species from the Río Cenepa Region (Croat, Yates & Swart, in press). Another collaborative effort with Lynn Hannon resulted in a revision of *Chlorospatha* (see section below on Lynn Hannon).

Other NSF sponsored projects have been completed or are being carried out, including a revision of *Philodendron* subg. *Philodendron* of Central America (Croat, 1997b), a revision of *Rhodospatha* (Croat, in prep.), and a revision of *Dieffenbachia* of Central America (Croat, 2004, in press.). In addition, *Anthurium* sect. *Semaeophyllum* has been revised with the help of Monica Carlson, University of Missouri-St. Louis, (Croat & Carlson, in prep.) and *Anthurium* sect. *Calomystrum* ser. *Rupicola* ser. nov. is being revised with the assistance of Jane Whitehill (Croat & Whitehill, in prep). These five revisions resulted in a total of 96, 67, 30, 22 and 8 species respectively with a total of 139 taxa (65, 52, 22, 6 and 3 species respectively) new to science. Additional new, as yet unpublished taxa have resulted from floristic studies. For example, 20 of the 50 species for Reserva La Planada in Colombia are believed to be new; 84 of 150 for the Flora of La Planada (Nariño); and 11 of the 31 taxa at the Reserva ENDESA in Ecuador. Many additional new species are being described in the Araceae treatment for the Flora of Lita-San Lorenzo (Esmeraldas), the Flora of Shell-



Mera (Pastaza), the Flora of Parque Nacional Sangay and the Flora of the Cordillera del Condor. To this date, Croat has published or has in press a total of 671 taxa. The resources that have been built up for aroid research at the Missouri Botanical Garden include one of the largest living collections of aroids and the largest collection of herbarium specimens of neotropical aroids. The living and dried collections include a large percentage of Croat's more than 94,000 personal collections. Finally, Croat organized a three day International Aroid Conference that followed the XVI International Botanical Congress in St. Louis in 1999.

Dorothy Shaw has published a series of mostly technical, experimental or ecological papers concerning the Araceae of Australia and Papua New Guinea. These include observations on the behavior of *Colocasia esculenta* (Shaw, 1975, 1982; Shaw *et al.*, 1979), pollination in *Alocasia macrorrhizos* (L.) G. Don [*A. brisbanensis*] (Shaw *et al.*, 1982; Shaw & Cantrell, 1983a, 1983b), fruit dispersal in *Alocasia macrorrhizos* (Shaw *et al.*, 1985), plant damage and fruit ingestion of seeds of *Alocasia brisbanensis* by birds (Shaw, 1998a) and lizards (Shaw, 1998b), stomata of *Monstera deliciosa* Liebm. (Shaw, 1992c), aroids of botanical gardens in Brisbane (Shaw, 1987), germination of *Typhonodorum* seeds in cultivation (Shaw, 1990) and the occurrence of the fungus *Puccinia* on *Monstera* (Shaw, 1991, 1992a, 1992b, 1993a, 1994, 1995a, 1995b). She published several papers on the endemic, monotypic *Gymnostachys anceps* including a paper dealing with habitat (Shaw *et al.*, 1997), fruit dispersal (Shaw *et al.*, 1997) and the seedling root and rhizome system with special reference to contractile roots (Shaw, 2002). Other papers dealt with postage stamps that exhibit plants of the family (Shaw, 1993, 1999), and phenology of *Alocasia brisbanensis* at Indooroopilly, Queensland (Shaw, 2004). With R. Greber she reported on the dasheen mosaic virus in Queensland (Greber & Shaw, 1986).

S. Serizawa published on Japanese *Arisaema* during the late 1970s and mid-1980s (Serizawa, 1975, 1980a, 1980b, 1981a, 1981b, 1982a, 1982b, 1986). These works, published only in Japanese, meant that he was not widely recognized internationally.

A brief research effort was made by Richard Baker at the Field Museum in Chicago. His efforts, before embarking on a new career in the early 1980's, were entirely in Costa Rica. With W. C. Burger, in charge of the *Flora Costaricensis* project at the Field Museum, Baker revised *Spathiphyllum* for Costa Rica (Baker & Burger, 1976). A few years later he collaborated with Tom Croat in the

revision of *Anthurium* for Costa Rica (Croat & Baker, 1979).

Mike Madison played an important role in the late 1970s and early 1980s before changing careers. He began with a flourish, publishing five papers the first year; two (Madison, 1976b, 1976c), dealing with new species (*Rhodospatha* and *Asterostigma* respectively), another comparing *Alloschemone* and *Scindapsus* (Madison, 1976a), and another comparing *Caladium* and *Xanthosoma* (Madison, 1976d), and finally a paper dealing with the seeds of *Monstereae* (Madison & Tiffney, 1976). His Ph.D. thesis, a revision of *Monstera*, was published the following year (Madison, 1977a). Though Madison did make an expedition to Brazil (Madison, 1979a), his principal fieldwork was in Ecuador where he collected widely, describing species in *Caladium* (Madison, 1981a), *Philodendron* (Madison, 1977b), *Stenospermation* (Madison, 1977c) and *Xanthosoma* (Madison, 1978e). In addition, he described a plant from Brazil as a new *Ulearum* (Madison, 1980). This later proved to be the new genus *Bognera*. Aside from his revision of *Monstera*, other major papers included a revision of the palmately-lobed *Anthurium* species (Madison, 1978g), a major paper discussing the ecology of the genera of Araceae of the northern Andes (Madison, 1978f), and a partial revision of the Caladieae (Madison, 1981a).

Madison published many miscellaneous short papers, especially while he was editor of *Aroideana*. These include reports on nomenclature (Madison, 1978a, 1978d), plant culture (Madison, 1978h), the living collections at Selby (Madison, 1978i), packing and shipping aroids (Madison, 1981b), *Monstera* seeds and the fossil record (Madison & Tiffney, 1976), the rediscovery of *Philodendron frits-wentii* (Madison, 1978b), and a synopsis of *Caladiopsis* (Madison, 1978j). Another includes the protection of developing seeds in Araceae (Madison, 1979b). He also wrote illustrative profiles of *Monstera deliciosa* (Madison, 1978c), *Xenophya* [= *Alocasia*] *lauterbachiana* (Madison, 1979c), *Anthurium lilacinum* (Madison, 1979d), *A. punctatum* (Madison, 1979f), and *A. superbum* (Madison, 1979e).

One of Madison's major accomplishments was the founding of the journal *Aroideana* with the International Aroid Society [see discussion below] in 1977. Madison began publishing the journal and was its editor for several years when he changed careers. Many of his earlier papers were written specifically for the journal. Madison was also responsible for organizing the first International Aroid Conference at Selby Gardens in Sarasota, Florida on March 28–29, 1980. These

conferences have been continued, albeit, irregularly, and they have contributed greatly to the dissemination of knowledge about aroids. With the completion of the conference in St. Louis, Missouri in August 1999, seven such conferences have been held, three of them in conjunction with the International Botanical Congresses. Aroid research was dealt a severe blow with Madison's retirement. This brilliant Harvard-trained researcher left a significant mark in his five short years of work with Araceae.

Wim Crusio, one of H. C. D. de Wit's students, completed a revision of the genus *Anubias*, and this excellent work was published twice, once in English (Crusio, 1979a) and once in German (Crusio, 1987). Another description of the genus and a discussion of its taxonomy also appeared in German (Crusio, 1980). Crusio has also published short papers on *Cryptocoryne* (Crusio, 1979b, 1979c). Along with Arie de Graaf he describes a new species of *Lagenandra*, *L. dewitii* (Crusio & de Graaf, 1986), and in another redescribes *L. ovata* Thwaites (Crusio & de Graaf, 1987).

Taking up where de Wit left off, Niels Jacobsen, from the Royal Veterinary and Agricultural University in Denmark, did additional work on *Cryptocoryne*, including extensive fieldwork in Southeast Asia. In a series of general papers he described the biology and ecology of *Cryptocoryne*. His first paper dealing with Araceae is about the ecology of *Cryptocoryne* (Jacobsen, 1976) while others deal with its pollination (Jacobsen, 1977a), chromosomes (Jacobsen, 1977b, 1977c; Arends *et al.*, 1982), and flowering behavior (Jacobsen, 1980a), vegetative morphology (Jacobsen *et al.*, 1989a-c) as well as with the description of new species (Jacobsen, 1977d, 1979a, 1980b, 1980e, 1981a, 1982, 1985a), a discussion of *C. undulata* (Jacobsen, 1981b), *C. ferruginea* (Jacobsen, 1980d), *C. cordata* (Jacobsen, 2002) and a revision of the *Cryptocoryne albida* complex (Jacobsen, 1980c). A 1991 paper (Jacobsen, 1991) treated the small-leaved *Cryptocoryne* species. A paper co-authored with Marian Ørgaard involved an SEM study of surface features in the spathes of *Cryptocoryne* and *Lagenandra* (Ørgaard & Jacobsen, 1998). In a series of papers with Josef Bogner, he revised the *Cryptocoryne* of the Malay Peninsula (Jacobsen & Bogner, 1986, 1987a-c) then published a complete revision for Borneo (Jacobsen, 1982, 1984, 1985b) and later for Ceylon (Jacobsen, 1988), and Tasek Bera (Jacobsen, 1986). These publications were precursors to his full revision of the genus. The complete revision of *Cryptocoryne* was published in two versions, one in Danish (Jacobsen, 1979b) and one in German (Jacobsen, 1979c). He will contribute *Cryptocoryne* for the Flora

Malesiana and is a coauthor of a checklist and bibliography for the region (Hay *et al.*, 1995a, 1995b). A paper in German in *Aqua-Planta* deals with the *Cryptocoryne* complex and includes two new combinations (Jacobsen, 2002) while another in the same issue coauthored with J. D. Bastmeijer and Y. Sasaki describes a new hybrid from Kalimantan (Jacobsen *et al.* 2002). Finally, Jacobsen published the treatment of the Arales in R. M. J. Dahlgren, H. J. Clifford & P. F. Yeo's, *The Families of Monocotyledons: Structure, Evolution and Taxonomy* (Jacobsen, 1985c).

Li Heng, working for the Chinese Academy of Sciences at the Kunming Institute of Botany and doing research on Chinese Araceae even before China's opening to the West, has become the authority on the family in China. Her earliest publication deals with the medicinal value of certain *Arisaema* (Li, 1976) and another, (Li *et al.*, 1977) "Claves diagnosticae et taxa nova Aracearum Sinicarum", provides a key to the genera of Araceae of China and describes 30 new taxa. Her principle interest is in *Arisaema*, including its phylogeography (Li, 1980a, 1980b, 1981) and taxonomy, describing many new species (Li, 1985, 1988a, 1992a, 1995, 2000; Li *et al.*, 1999; Peng Hua & Li Heng, 1995) as well as *Amorphophallus* (Li, 1988b-d; Li *et al.*, 1989, 1990; Li & Long, 1989; Long *et al.*, 1989; Yi & Li, 2001), *Typhonium* (Li & Zgeb-quian, 1983), *Remusatia* Schott (Li, 1987a, 1991, 1992b; Li & Hay, 1992b; Long *et al.*, 1989b), *Rhaphidophora* (Li, 1992b), *Gonatanthus* [later reduced to *Remusatia*] (Li, 1987b; Li & Hay, 1992b), and *Colocasia* (Li & Wei, 1993). Her papers frequently deal with cytological details of the species described (Gu *et al.*, 1992; Li *et al.*, 1989). Still others deal with floristics such as that of the Dulongjian Region (Li, 1993b), Xizang area (Li, 1987c), the Gaoligong Mountains (Li *et al.*, 1999), the Hengduan Mountains (Li & Li A.M. 1983, 1994), the Wuliangshan Mountains (Peng Hua & Li Heng, 1998), or plants of medicinal value (Li, 1988, 1990). Papers dealing with the phylogeography of the Araceae (Li 1986, 1996, 1999), divide the family into 12 distribution patterns and 29 subpatterns; and others deal with the origin and phylogeny of Araceae (Li, 1983, 1999). Li presented a paper at the XVI International Botanical Congress in Yokohama dealing with the species diversity of Chinese Araceae (Li, 1993a). Perhaps her major accomplishment is the treatment of the Araceae of China written with C. Y. Wu (Li, 1979a, 1979b) that deals with 34 genera and 191 native species. The largest aroid genus in China, *Arisaema*, is reported with 82 species. Li Heng is also chiefly responsible for the treatment of the Araceae in the "Iconographia cormophytorum sinicorum (Anonymous, 1976) published by an editorial

committee of that publication. This work treats 26 genera and 51 species, all illustrated with line drawings. Li is currently working on the English version of the Flora of China and presented information about that project at the VI and VIII International Aroid Conferences (Li & Long, 1998a). Another recent paper (in Chinese) (Li & Long, 1998b) deals with the taxonomy of *Amorphophallus* and includes a key to the Chinese species.

Also in China in the same year, Kao Pao-Chung [Gao Baochun], working with the Academia Sinica in Chengdu, Sichuan, did a revision of the Araceae for the Flora Sichuanica (Kao, 1989a) and described new species of Araceae (Kao, 1989b). That flora, not as tropical as Yunnan, treated 13 native genera and 62 native species.

In southwestern China, Liu Pei-Ying at the Research Center of Konjac at the Southwest Agricultural University in Chongqing, has been working on *Amorphophallus* breeding. She presented a paper at the VI International Aroid Conference in Kunming entitled "Research and Utilization of *Amorphophallus*" (liu, Zhang & Zhang, 1998).

Simon Mayo of the Royal Botanic Gardens, Kew is today one of the foremost aroid researchers. His first paper dealing with Araceae was a report on his early fieldwork in Brazil (Mayo, 1978a), making it one of the first contributions in the new journal *Aroideana*. His next two papers (Mayo, 1978b; Mayo & Barroso, 1979) dealt with Brazilian species, and his interest in Brazilian Araceae continues to this day (Mayo, 1983a, 1986e, 1987c, 1988b, 1989b, 1995; Mayo & Barbosa, 1996; Mayo & Féliz, 2000; Mayo & Feveireiro, 1982; Mayo & Zappi, 1993; Feveireiro & Mayo, 1982; Mayo *et al.*, 1995; Sampaio *et al.*, 1996). Mayo has in recent years lived and worked in Brazil where he has taught and organized the research of several Brazilian students who were interested in Araceae (Mayo & Nadruz, 1992; Ramalho, 1995; Sakuragui, 1994; Nadruz, 1995; Andrade, 1996; Soares, 1996; Sakuragui & Mayo, 1997). Together with Brazilian colleagues, he has prepared a checklist for all of Brazil (Mayo *et al.*, in prep.) and has been especially interested in the Atlantic coastal regions (Mayo, 1990b). He has published papers on the phytogeography (Mayo, 1984b) and taxonomy of Bahía (Harley & Mayo, 1980; Mayo, 1984b) and has recently prepared a revision of the Araceae of Bahía (Mayo, manuscript). On a broader topic Mayo discussed aroid phytogeography in Africa and South America (Mayo, 1993). Other Mayo papers dealing with New World aroid species are those describing a new *Caladium*

(Mayo & Bogner, 1988) and rediscovering *Gearum* N. E. Br. (Mayo *et al.*, 1994).

Among Mayo's earliest efforts were with the flora of Trinidad (Mayo, 1981, 1986a) and with taxonomic problems in the West Indies, such as a resolution of the poorly understood *Anthurium acaule* and its relationship to the *A.* sect. *Pachyneurium* (Mayo, 1982a). Mayo has also been heavily involved with African Araceae, and he has produced the treatment of the Araceae for the *Flora of the Mascarene Islands* (Mayo, 1983b, 1984c) and the *Flora of Tropical East Africa* (Mayo, 1985a). This in turn has led to considerable involvement with the taxonomy of African *Amorphophallus* (Mayo *et al.*, 1982; Bogner *et al.*, 1985), Araceae in the *Flora of Cyprus 2* (Mayo & Meikle, 1985), and *Arisaema* (Mayo, 1982b, 1984a, 1985b, 1986b, 1987a, 1987b; Mayo & Gilbert, 1986). A short paper deals with *Biarum* (Mayo, 1980a) while others focus on aroids at Kew (Mayo, 1979) and an aroid symposium at Selby Gardens (Mayo, 1980b). Still another paper discusses the presence of anthocyanins and flavonoids in the Araceae (Williams *et al.*, 1981). Mayo's participation in a special volume of *Curtis's Botanical Magazine* resulted in articles dealing with the "Genera of Araceae" project (Mayo *et al.*, 1995a, 1995b, 1995e), and Roberto Burle Marx (Mayo, 1978c, 1982c, 1982d; Mayo *et al.*, 1995c). He has also reviewed various books on Araceae (Mayo, 1980d, 1982d, 1983c, 1986c, 1991b).

For his Ph.D. work Mayo chose to do a revision of *Philodendron* subg. *Meconostigma* (Schott) Engl. (Mayo, 1986d) but his work went well beyond *Meconostigma*, leading him to conduct research in various aspects of the whole Philodendroideae. In a series of papers he discusses the evolution (Mayo, 1988a), the gynoeclial structure (Mayo, 1989a), and the taxonomy of *P.* subg. *Meconostigma* (Mayo, 1991a); and the history and infrageneric nomenclature of *Philodendron* (Mayo, 1990). He was the first to formally recognize tribe *Pteromischum* as a subgenus. Mayo has subsequently put all of his information on this group and other genera together in a massive computer-driven cladistic study to reappraise the suprageneric classification of the Araceae. This system is presented in *The Genera of the Araceae* (Mayo *et al.*, 1997). Using the same cladistic information, the authors (including J. Bogner & P. Boyce) present the case for the inclusion of the Lemnaceae into the Araceae as a subclade of a monophyletic Araceae (Mayo *et al.*, 1995). They have also completed a treatment of the Araceae in K. Kubitzki's *The Families and Genera of Vascular Plants* (Mayo *et al.*, in press), and done an article on the acolytes of the Araceae (Mayo *et al.*, 1995d).

Simon Mayo's decision in 1973 to leave the Horticulture Department at Kew Gardens and to become involved with the taxonomy of the Araceae was an important event for research with the Araceae. His research, especially his broad general studies in the evolution of the Philodendroideae and his cladistic studies that have reclassified the genera of Araceae, are on the cutting edge.

Richard Sheffer did important breeding studies and cytological work with *Anthurium* during his Ph.D dissertation (Sheffer, 1974, 1977) at the University of Hawaii and later at Indiana University Northwest. The work was carried out in part with his major professor, cytologist and *Anthurium* breeder H. Kamemoto (Sheffer & Kamemoto, 1976a, 1978; Sheffer *et al.*, 1980). Sheffer published a review of chromosome numbers for *Anthurium* (Sheffer & Kamemoto, 1976b; Sheffer & Croat, 1983), and he conducted a cytotaxonomic study of the *Anthurium scandens* complex (Sheffer *et al.*, 1980). Another major accomplishment was breeding studies carried out with *Anthurium* sect. *Pachyneurium* (Croat, 1991a) [see also Kamemoto above]. Sheffer has a new greenhouse facility filled with Araceae that he uses in his cytological research.

Another important plant breeder dealing primarily with Araceae is R. J. (Jake) Henny from the Central Florida Research and Education Center, University of Florida in Apopka. His work has been largely experimental involving culture techniques of *Aglaonema*, *Anthurium*, *Dieffenbachia*, and *Spathiphyllum* (Henny, 1980a, 1989a, 1989b; Henny & Fooshee, 1990a, 1990b; Henny *et al.* 1980a, 1994, 1995), the use of growth regulators to induce flowering (Henny, 1980b, 1981, 1983a, 1983c, 1988c, 1989b, 1991, 1992; Henny & Fooshee, 1983, 1989b, 1990b, 1990c, 1991; Henny & Rasmussen, 1980b), breeding (Henny, 1982a-c, 1983b, 1984, 1988a, 1989a; Henny & Rasmussen, 1980a, 1980c, 1980d, 2000), and aroid introductions (Henny, 1988b, 1995a, 1995b; Henny *et al.*, 1987a, 1987b). Henny recently published a manuscript on progress in ornamental Aroid breeding research (Henny *et al.* 2004). Ann Chase, also from the C.F.R.E.C.-Apopka, works on aroid research and has published results on various cultural aspects (Chase, 1989; Chase & Henny, 1990; Chase & Poole, 1991) as have C.A. Conover (Conover & Henny, 1995), R.W. Henley (Henley, 1992), and D. Norman (Norman, 1996).

Marija Bedalov, working at the University of Zagreb in Croatia, has worked many Araceae of the Balkan region. Her Ph.D. thesis, written in Croatian, dealt

with the cytotaxonomy of the Araceae of Yugoslavia (Bedalov, 1973a, 1976b). Since then she has worked with several genera including *Arisarum* (Bedalov & Bronic, 1999), *Biarum* (Bedalov, 1969b), *Calla* (Bedalov, 1983b, 1994), and *Dracunculus* (Bedalov, 1972, 1976b, 1994; Bedalov & Hesse, 1999), but most of her work has been with *Arum*, especially dealing with aspects of cytology, phytogeography and palynology (Bedalov, 1975a-c, 1976a, 1977, 1978, 1980, 1981a, 1981b, 1982, 1983a, 1984, 1985, 1999; Bedalov & Guttermann, 1982; Bedalov & Bronic, 1989; Bedalov & Hesse, 1989; Bedalov *et al.*, 1991; Bedalov *et al.*, 1993a, 1993b, 1999a, 1999b; Bianco *et al.*, 1994; Bedalov & Fischer, 1995; Bedalov & Drenkovski, 1997; Bedalov & Bronic (1998a, 1998b; Bedalov *et al.*, 1998). She also has been very active publishing chromosome reports (Bedalov, 1973; Favarger & Bedalov, 1998) and especially in IOPB Chromosome Data 10 [see list of literature]. With M. Hesse she has studied pollen types within *Dracunculus* (Bedalov & Hesse, in prep). Other papers in preparation include a cytotaxonomical study of *Arisarum vulgare* (Bedalov & Bronic, in prep.), a paper on the artificial hybridization in *Arum* (Bedalov *et al.*, in prep), on observations in meiosis in *Arum* (Bedalov *et al.*, in prep), and on studies with *Arum* in Denmark (Bedalov *et al.*, in prep).

Bedalov has also dealt with the cytology and phytogeography of *Calla* and *Acorus* (Bedalov, 1983b). Her work has largely been concentrated in the Balkan region, especially in the former Yugoslavia. A participant in the first International Aroid Conference as well as third, fourth and sixth, she is an active and productive researcher. In addition to her work in Zagreb, she carries out independent investigations with a colleague in Switzerland.

Jin Murata, an expert on Asian *Arisaema*, published his first paper on *Arisaema* late in the decade (J. Murata, 1978). Several other papers describing new species followed (J. Murata, 1956, 1983a, 1985a; J. Murata & Ohashi, 1980; J. Murata & Ohno, 1989; J. Murata & S. Wu, 2003; J. Murata *et al.*, 1994), one on a new combination in *Typhonium* (J. Murata & Mayo, 1991) and another describing the first leaves of a species (J. Murata, 1986a). Murata provides keys, photos and a discussion of the Japanese species of *Arisaema* (J. Murata, 1990a), in Aroideana. Other papers include information on chromosomes of *Arisaema* (J. Murata, 1983b, 1990b; J. Murata & Iijima, 1983), a study of the stem morphology (J. Murata, 1988), a study of shoot organization recognizing four types of stems (J. Murata, 1990c), and a study of developmental pattern of pedate leaves (J. Murata, 1990d) and allozyme differentiation in *Arisaema* (J. Murata &



Kawahara, 1994a-c; M. Maki & J. Murata, 2001). Two papers deal with attempts of infrageneric classification (J. Murata, 1984, 1990f) and others deal with revisions of minor groups or species complexes of *Arisaema* (J. Murata, 1962, 1985b, 1986b, 1986c, 1990d, 1990g, 1991, 1995; J. Murata & Ohno, 1991). Murata also wrote a memoriam for Hiroshi Hara (J. Murata, 1987).

Among Murata's major publications is a complete revision of *Arisaema* in Japan (Ohashi & J. Murata, 1980), complete with keys and illustrations [see Ohashi above] and a proposed infrageneric classification of *Arisaema* (J. Murata, 1984). Murata also participated in the research of his student, Duangchai Sriboonma in a molecular study of the genus *Typhonium* (Sriboonma *et al.*, 1993) and a revision of the genus (Sriboonma *et al.*, 1994). Murata has recently published an extensive review of the cytology of *Arisaema* with the help of senior author Kuniaki Watanabe and Tomiki Kobayashi (K. Watanabe *et al.*, 1998). Murata also co-authored papers discussing *Arisaema seppikoense* and the *Arisaema undulatifolium* group with Watanabe and Kobayashi, the latter as senior author (Kobayashi *et al.*, 1999, 2000).

Murata is a member of the team of taxonomists working on the Araceae treatment for the Flora Malesiana and is a coauthor of a checklist and bibliography for this region (Hay *et al.*, 1995, 1995a). He organized the VI International Aroid Conference as a part of the XI International Botanical Congress in Yokohama in 1993.

Another Japanese botanist, sometimes publishing with Hotta, is H. Okada. His work has been largely experimental and behavioral, including cytotaxonomical studies of populations of Araceae in West Sumatra (Okada, 1984, 1986), studies of population dynamics of *Schismatoglottis* in Sumatra (Okada, 1989; Okada & Hotta, 1987; Okada & Mori, in press) as well as on chromosome behavior in *Colocasia* (Okada & Hambali, 1989) and *Schismatoglottis* (Okada, 1992a). Two other papers discuss cytotaxonomic studies of rheophytic aroids (Okada, 1992b, 1993).

Tomiki Kobayashi from the Hyogo Prefectural Institute of Environmental Science in Kobe, Japan did graduate work under H. Kamemoto at the University of Hawaii. He has published with Kamemoto on using gel electrophoresis to identify *Anthurium* cultivars (Kobayashi *et al.*, 1987). He published a review of the cytology of *Arisaema*, and was also senior author of two recent papers

discussing *Arisaema seppikoense* and the *Arisaema undulatifolium* group (K. Watanabe *et al.*, 1998; Kobayashi *et al.*, 1999, 2000).

Working in Hungary on *Arum*, A. Terpo has made studies on the distribution and taxonomy of *Arum* species (Terpo, 1971, 1973) in Pannonian territories (now mostly Hungary and Yugoslavia).

Toward the end of the 1970s, P. Blanc in France carried out important studies on the growth behavior of the Araceae. These studies (Blanc, 1977a, 1977b, 1978, 1980) were a precursor to the more extensive growth behavior studies carried out by Tom Ray (see below).

As mentioned earlier, the late 1970s also saw the creation of the International Aroid Society, known initially as the American Aroid Society. This organization, founded in Miami, Florida on June 18, 1977, was started through the inspiration of Bette Waterbury, Allen Fernández, John Faust, Shirley Crete, Marilyn Turner, Peggy Fischer (all constituting the first officers with Waterbury as president), Tom Fennell, Monroe Birdsey, Ron Weeks, De Hull, Gary Antosh, Joan Hackler, and others. In the words of Michael Madison, in the leading article of *Aroideana*, the International Aroid Society was intended to "promote the study of the aroid family in all of its aspects." Madison started publishing the society's journal, naming it *Aroideana* at the suggestion of Dan Nicolson. The society and certainly the journal have had their share of difficulties, mostly the result of a volunteer-driven and sometimes inadequately prepared staff, but also because of editors who gave up, and even one (Mark Moffler) who died suddenly, along with the many difficulties in finding the right publisher. The journal has by all accounts been immensely valuable in dealing with Araceae. Many of the papers published throughout the years simply would not have been written at all had it not been for the need to "feed the presses." Major contributors in the first few years were Madison himself, Simon Mayo, Josef Bogner, Tom Croat, and Harald Riedl. Other aroid researchers who contributed were George Bunting, Niels Jacobsen, Tom Ray, Dan Nicolson, Alistair Hay, Peter Boyce, M. Sivadasan, Richard Sheffer, Dorothy Shaw, Mike Grayum, Richard Henny, H. Kamemoto, Marianne Knecht, Farah Ghani, Larry Klotz, and Mark Moffler.

From the onset, the journal has encouraged and received articles from horticulturists and plant collectors since plant lovers of all kinds primarily support the aroid society. Many of them have contributed greatly, such as Bette

Waterbury, John Banta, Frank Brown, an expert on the genus *Aglaonema* (Brown, 1980, 1982, 1984), Fred Dortort, Amy Donovan, Lawrence Garner, dealing with hybridizing *Alocasia* (Garner, 1983), James Watson, Luis Bueno, Julius Boos, David Leedy, Linda Theus, David Prudhomme, John Johnston, Joe Wright, Mike Bush, William Drysdale, Marcel Lecoufle, Stu Cramer, and Arnold Melim. Naturalist Julius Boos, a recent contributor, is particularly knowledgeable about the aroids of Trinidad and some members of the Lasioideae (Boos, 1997), especially *Urospatha* (Boos, 1993; Boos & Boos, 1993). Fanny Phillips made an important contribution to the understanding of *Amorphophallus* (Phillips, 1988). Libbe Besse wrote a paper on the native south Florida aroids (Besse, 1980). She has also played an important role in the development of Selby Gardens and has sponsored and participated in several important expeditions to Ecuador with Mike Madison and others at Selby Gardens. These expeditions were among the most productive, ever, in the procurement of living Araceae and her assistance is to be commended. David Burnett made a major contribution where he contributed an unpublished table of contents to earlier *Aroideana* volumes that was useful in preparing the published indices (Croat & Rossman, 1991; Donovan & Malesevich, 1994), and he published an illustrated introduction to the cultivated *Alocasia* (Burnett, 1984). Since there is no modern revision of this genus, the work by Burnett has been immensely useful. Another paper discusses a proposal for hybrid and cultivar names (Burnett, 1982).

In addressing the success of the journal and the International Aroid Society itself, both of which have been instrumental in promoting activity with Araceae, a major tribute must go to a small band of enthusiasts in Miami who have provided the impetus to keep things running. The faces have changed over the years although many devoted members are worthy of mention, only a few can be mentioned here. Foremost is the late Bette Waterbury, founder and first president (who also served subsequent terms) and president emeritus, who did so much to keep the society alive. Other productive members such as Linda Theus, Allen Fernandez, and Maree Winter are no longer with us. Special thanks must go to people like Amy Donovan, present editor of the journal and one of the most dedicated society members; Dewey Fisk who served as board member, President, Corresponding Secretary, journal editor, plant sale promotor and auctioneer; David Burnett, who served as a board member, recruited many Australian members and ran Australian membership affairs; David Leedy who served as newsletter editor; Bruce McManus who served as newsletter editor, membership chairman and especially as Show Chairman for the annual meeting and show;

Denis Rotalante, Ron Weeks and others who could always be counted on to bring big plants for the Annual Show and Sale; Tricia Frank, Susan Staiger, Jerry Bengis, Donna Rich, and many others who have served as officers or who were heavily involved in the work of putting together the Annual Meeting and Show are all to be commended for their efforts. Petra Schmidt, who was assistant for many years, first as aroid greenhouse manager and later as research assistant, is one of the unsung heroes of the aroid community. She has served as a board member, membership chairperson, assistant editor, book sales and compiler of membership lists and *Aroideana* indices in addition to carrying out the multitude of tasks necessary in my own research program. Finally, the many others who were there making the society work; they are the ones who sold the plants, the T-shirts and books to make the profits which kept the journal in publication during the lean years. Certainly all of us owe them a debt of gratitude.

The 1980s were, in many respects, some of the most important years for aroid research. This period saw the greatest increase of knowledge since the time of Engler, Krause and Sodiro, around the turn of the century. Most researchers who had begun their work in the 1960-1970's were still active. It was also a time of real ferment with a number of excellent, new, well-trained researchers beginning their careers with Araceae. Peter Boyce at Kew began work with Mediterranean Araceae. The focus of research on Araceae also became increasingly diverse; no longer mostly systematic, but instead focus widened to a number of behavioral and experimental approaches. Hegnauer reviewed the chemical attributes of the Araceae (Hegnauer, 1963, 1986, 1987). Tom Ray began working with a wide variety of aspects of growth behavior (See, Ray below). H. J. Tillich reported on seedling development (1985). Jim French conducted an extensive and comprehensive review of technical aspects of the Araceae, including a wide spectrum of anatomical features and a broad molecular survey before embarking on studies with pollination biology of the Araceae (See French below). Mike Grayum startled the aroid world with his astounding new suprageneric classification that followed his thorough SEM review of pollen and a review of virtually all character states in the Araceae (Grayum, 1984). Marianne Knecht published her biosystematic study of the Araceae of the Ivory Coast. Denis Barabé began studies of floral anatomy. William Carvell followed with studies on the Pothoideae and Monsteroideae (Carvell, 1989a; 1989b). Robin Scribailo at Purdue North Central in Westville, Indiana, is now doing similar studies on floral anatomy. He published work on the developmental anatomy of *Peltandra* (Scribailo & Lloyd, 1993) and on shoot and floral development in *Calla*

(Scribailo & Tomlinson, 1992). Gitte Petersen began her work with the cytology of the Araceae (see "Miscellaneous Disciplines" below). Helen Young (currently at Barnard College in New York), working at La Selva in Costa Rica, observed *Philodendron rothschuhianum* (Engl. & K. Krause) Croat & Grayum (Young, 1987), and often with the assistance of George Schatz (Missouri Botanical Garden) studied reproductive biology of *Dieffenbachia* (Young, 1986, 1988a, 1988b) thereby discovering many interesting features that gave insight into all other beetle pollinated genera. Lloyd Goldwasser (University of California) worked on similar pollination projects. Long Chun-lin, working with Li Heng at the Kunming Institute of Botany, began working with Chinese Araceae. Finally, this decade saw one of the first and certainly the best book devoted to Araceae written for the general public, *Aroids*, written by Deni Bown, an amateur aroider and a highly regarded professional writer. Her book has gone a long way toward introducing Araceae to the general public. It is not only highly informative, but it is easy reading and is filled with excellent pictures (Bown, 1988). She also contributed papers for *Aroideana* on naturalized English aroids (Bown, 1985) and on the history of *Acorus calamus* L. (Bown, 1987) to *Aroideana*.

The published aroid research of James C. French, first at the University of Mississippi and later at Rutgers, began in the early 1980s. Perhaps no aroid worker was ever as prolific over a single decade. His first paper (French, 1977) dealt with growth relationships of leaves and internodes in vining angiosperms with different modes of attachment. His first paper dealing exclusively with Araceae was a collaborative survey of the vascular system in Araceae (French & Tomlinson, 1980). A series of papers followed which revealed the vascular anatomy of all the subfamilies: Pothoideae (French & Tomlinson, 1981a), Philodendroideae (French & Tomlinson, 1981b, 1984), Calloideae and Lasioideae (French & Tomlinson, 1981c), Monsteroideae (French & Tomlinson, 1981d), and Colocasioideae, Aroideae and Pistoideae (French & Tomlinson, 1983). Another work dealt with a much larger survey of *Philodendron*, a genus of especially variable vascular anatomy (French & Tomlinson, 1981b) while still another dealt with stems in general (French, 1983). French also embarked on an independent survey of a variety of anatomical features with the hope of understanding their taxonomic significance. These included meristems (Fisher & French, 1976, 1978), endothelial thickenings in stamens (French, 1985a, 1985b, 1986c), ovular vasculature (French, 1986a), sclerotic hypodermis in roots (French, 1987a), anastomosing laticifers (French, 1988), and patterns of staminal vasculature (French, 1986b). With M. G. Fox he studied the systematic occurrence of sterols

in the latex of Colocasioideae (Fox & French, 1988). These broad surveys contributed greatly to a better understanding of the evolution of the Araceae and the attempt, so intense at that time, to resolve the differences in competing systems of classification (Grayum, 1984; Bogner & Nicolson, 1991).

In a thorough survey of the chloroplast DNA of Araceae (French *et al.*, 1995), French and his colleagues contributed greatly to the most recent revision of the suprageneric classification of the Araceae (Mayo *et al.*, 1997). Other molecular studies dealt with *Acorus* and *Gymnostachys* (French & Kessler, 1989) and the Colocasioideae (Kessler & French, 1989). Jim French has covered a variety of distinct research topics in Araceae and has done them all well. His latest approach is with the pollination biology that he is conducting during his sabbatical while living with his family in Costa Rica.

Alistair Hay began his career in New Guinea and published a treatment of the Araceae of Papua New Guinea (Hay, 1981). For his Ph.D. dissertation he revised *Cyrtosperma* (Hay, 1986, 1988a). With D. J. Mabberley he published a paper (Hay & Mabberley, 1991) on a controversial theory of evolution in Araceae and discussed its implication for the evolution of other angiosperms. Hay, now working at the Royal Botanic Gardens, Sydney in Australia, had a major interest in Australasia and published a treatment of *Alocasia* for Australasia with R. Wise (Hay & Wise, 1991), discussed collecting *Alocasia* in New Guinea (Hay, 1990a), did a revision of *Typhonium* (Hay, 1993a), and *Amorphophallus* (Hay, 1988b) for Australasia, described the new genus, *Lazarum*, discovered in Australia (Hay, 1992a), published the Araceae of New South Wales (Hay, 1993b), and new taxa of *Alocasia* (Hay, 1989, 1994; Hay *et al.*, 1997 in press), *Colocasia* (Hay, 1996b), *Nephtytis* in Borneo (Hay *et al.*, 1994), *Rhaphidophora* (Hay, 1993c), and aroids of Papua New Guinea (Hay, 1990b). Recently he completed a revision of the genus *Pothos* for New Guinea, Solomon Islands, and Australia (Hay, 1995), introduced a new species of *Typhonium* (Hay & Taylor, 1996), a revision of *Schismatoglottis* for Peninsular Malaysia and Singapore (Hay, 1996a), and a revision of the Schismatoglottideae of Malesia (Hay & Taylor, 2000; Bogner & Hay, 2000). He is also publishing a revision of *Homalomena* in New Guinea, the Bismarck Archipelago and Solomon Islands (Hay, 1997a), an article on *Alocasia melo* (Hay *et al.*, 1997), and on new species of *Typhonium* (Hay, 1997b). Hay has recently revised *Alocasia* in the Philippines (Hay, in press), reviewed *Schismatoglottis* in the Philippines (Hay, in press) and is working on a treatment of the Flora of Australia (Hay, in prep.), a revision of *Alocasia* in West Malaysia

(Hay, in prep.), and a popular account of the Araceae of Sabah and Sarawak (Hay, in prep.). Other recently completed papers involve studies with shoot architecture in *Pothos* (Hay, in press) and a discussion of the value of living collections for taxonomic studies and for conservation (Hay, in press).

Hay's interest has continued with the subfamily Lasieae worldwide. He described the neotropical genus *Anaphyllopsis* A. Hay (Hay, 1988c) and discussed the tribal and subtribal distribution and circumscription of the Lasieae (Hay, 1992b) as well as the proper circumscription of *Lasia concinna* Alderw. (Hay, 1988d). Currently Hay is the coordinator of the Araceae treatment for the Flora Malesiana (Hay, 1994b), a project involving contributions from about a half dozen aroid taxonomists from all over the world, including, in addition to Hay, Josef Bogner, Peter Boyce, Wilbert Hetterscheid, Niels Jacobsen, Jin Murata, and Elizabeth Widjaja. A recent joint effort by several of these contributors has resulted in a checklist (Hay *et al.*, 1995a) and a bibliography (Hay *et al.*, 1995b). As the prime mover on the Flora Malesiana project and a member of the Flora Malesiana Foundation Board, his contribution to aroid research is certain to continue to be profitable.

Tom Ray carried out studies on growth and heterophylly on *Syngonium* for his Ph.D thesis at Harvard (Ray, 1981). While working at the University of Delaware, he played an important role in understanding growth of Araceae and his first paper in Araceae dealt with skototropism (Strong & Ray, 1975). Other early papers describe the physical aspects and variability of growth behavior in general terms (Ray, 1979) and use of specific cases to demonstrate growth behavior (Ray, 1983a, 1983b; Oberbauer *et al.*, 1980). In another paper (Ray, 1986) he began to define terms and discuss the universality of the stem segment regardless of its age. In another he discusses cyclic heterophylly of plants displaced from trees (Ray, 1987a). In a paper entitled "Leaf types in the Araceae" (Ray, 1987b) he begins to define the complex terminology that will become a part of his work. In the next two papers (Ray, 1987c, 1988) the system is further defined and a schematic formulation is provided for each type of shoot organization. Ray also describes metamorphosis, i.e. the abrupt change from one growth form to another, and discusses how this varies in different genera (Ray, 1990, 1992a). Another paper discusses a novel method to measure and record leaf shape using *Syngonium podophyllum* Schott as a test case (Ray, 1992b). Though not a systematist, Ray did describe a new species of *Syngonium* (Ray, 1980). Ray's comparative surveys of most genera proved very useful in helping to sort out the generic relationships.

With the assistance of Susanne Renner (Ray & Renner, 1990) he translated Part 2 of Engler's (1877) "Comparative Studies on the Morphology of the Araceae." This information was yet another important element in the body of knowledge accumulated during this productive period of Araceae research. Unfortunately for aroid research, Ray has embarked on another field of learning. His high intellect and imagination will be sorely missed in Araceae research.

Hiromichi Yoshino from Kyoto University in Japan explored the Himalayas of Nepal and Bhutan (and wrote two general interest books on the subject) before he began his work with Araceae at the Kihara Institute for Biological Research in 1975, continuing his studies after he moved to Okayama University, publishing molecular studies on *Colocasia* and *Alocasia* in Japan and China (Yoshino, 1975, 1994). Another paper describes the morphological characteristics of the wild species of *Colocasia* (Yoshino, 1984). His Ph.D. dissertation dealt with a phylogenetic differentiation in taro, *Colocasia esculenta* (Yoshino, 1995). Other papers deal with phosphate and nitrate absorption ability of wild species of taro (Yoshino, 1995) and morphological and genetic variation in cultivated and wild taro (Yoshino, 2002).

Michael H. Grayum, while still a student at the University of Massachusetts, spent a summer in Costa Rica working at La Selva. His first paper dealing with Araceae described the characteristics of that flora (Grayum, 1982). His Ph.D. thesis, written at the University of Massachusetts, involved an SEM study of pollen, but in characteristic thoroughness, he studied every other known character state as well, and on this basis he developed a new system of classification of the genera of Araceae (Grayum, 1984). The system, quite at odds with that of Engler, has for the most part proven over time to better fit our modern state of knowledge of the family. Other papers dealing directly with the information assembled for his thesis include: one on the evolution and ecological significance of starch in pollen of Araceae (Grayum, 1985), the phylogenetic implications of pollen nuclear number in the Araceae (Grayum, 1986a, 1986b), correlation between pollination biology and pollen morphology with some implications for angiosperm evolution (Grayum, 1986b), and the systematic embryology of the Araceae (Grayum, 1991). The bulk of his thesis was published under the titles "Evolution and Phylogeny of the Araceae" (Grayum, 1990) and "Comparative External Pollen Ultrastructure of the Araceae and Putatively Related Taxa" (Grayum, 1992a). Another major contribution was his investigations supporting the removal of *Acorus* from the Araceae, listing 13 unique characteristics of



*Acorus* not shared with other Araceae (Grayum, 1987a).

Grayum's principal work with Araceae, since his thesis, has involved Costa Rica where he lived for seven years, and with a revision of *Philodendron* subg. *Pteromischum* (Grayum, 1996). Some new species of *P.* subg. *Pteromischum* have been published (Grayum, 1992b, 1996) as well as a new *Anthurium* (Grayum, 1993). He has also had an interest in *Caladium* and *Chlorospatha* (Grayum, 1987b, 1991b). Grayum now serves as Editor of the Annals of the Missouri Botanical Garden and co-investigator of the Costa Rican Manual project. His latest efforts in this project involved a revision of the Araceae of Costa Rica. This has resulted in his current paper (Grayum, in press).

Marianne Knecht, from Switzerland, did a biosystematic study of the Araceae of Côte d'Ivoire (Ivory Coast) in tropical West Africa. This was a thorough study of every aspect of each species occurring there from morphology to phytogeography, cytology, anatomy, palynology and flowering behavior. The results are published in a book in French (Knecht, 1983). Another paper deals with African traditional medicine (Knecht, 1980).

M. Sivadasan (Das), from the University of Calicut in Kerala, India, has worked with the Araceae extensively since the mid-1970s. His unpublished doctoral thesis was a taxonomic study of the Araceae of South India (Sivadasan, 1982). His first published paper described a new species of *Typhonium* (Sivadasan & Nicolson, 1981), and his first major production was a revision of *Theriophonum* (Sivadasan & Nicolson, 1982). Other publications include popular articles published on rare Indian aquatic plants, including *Cryptocoryne* (Sivadasan, 1985a, 1989b) and *Lagenandra* (Sivadasan, 1990; Sivadasan & Babu, 1995; Sivadasan & Bogner, 1986), and he co-produced the Araceae for the flora of Tamilnadu Carnatic (Sivadasan & Nicolson, 1983). Sivadasan (1983) also wrote on threatened species of Indian aroids as well as the description of new species or new names of *Arisaema* (Sivadasan, 1985b; Sivadasan & Kumar, 1987; Sivadasan & Nicolson, 1981, 1983a), *Lasia* (Sivadasan & Sajeev, 1996), *Amorphophallus* (Sivadasan, 1986a, 1986b, 1989a), *Pothos* (Sivadasan *et al.*, 1989; 1994), and *Theriophonum* (Sivadasan & Wilson, 1997, in press). Another paper discusses the pollination biology of *Amorphophallus* (Sivadasan & Sabu, 1989). In collaboration with C. R. Suresh and K. S. Manilal, he discussed the taxonomy of aroid species in H. A. van Rheedee tot Draakestein's *Hortus Indicus Malabaricus*. A recent addition to the study of the Indian flora is his study of the

Araceae of the Silent Valley area (Sivadasan, 1999). This treats 9 genera and 21 species with 17 color figures. Currently, Sivadasan has an article in press with the journal *Aroideana* concerning flowering phenology and beetle pollination in *Theriophonum infaustum* N. E. Br.

Peter Boyce's interest in Araceae began about 1980. He was involved in the cultivation of aroids and exploration, made a collecting trip to Crete as early as 1986 (Boyce, 1986). In his official capacity at the Royal Botanic Gardens at Kew, he began his work with Araceae as Simon Mayo's assistant. He properly chose to work in a different part of the world than Mayo, initially doing revisionary work with the Mediterranean genera, especially *Arum*, about which he has published a book (Boyce, 1993a). This work, complete with color paintings, covers all aspects of the taxonomy and biology of the genus. A similar book, this one dealing with *Biarum*, is to be published. Other publications on Mediterranean plants deal with *Arisarum* (Boyce, 1989, 1990), *Biarum* (Boyce, 1987b, 1995h, 1999; Boyce & Athanasiou, 1991), *Arum* (Boyce, 1987a, 1988, 1989, 1994a, 1995j), and include descriptions of new species. Boyce has also published a treatment of both *Dracunculus* and *Helicodiceros* (Boyce, 1994b).

As noted above, Boyce is a member of the team working on the Araceae for the Flora Malesiana and has coauthored a checklist and bibliography of the region (Hay *et al.*, 1995, 1995a) and written about collecting in Peninsular Malaysia (Boyce, 1994). He is responsible for *Epipremnum* (Boyce, 1998), *Pothos* (Boyce, 2000), *Rhaphidophora* (Boyce, 1999), and *Scindapsus*. He is also doing the Araceae for the Flora of Brunei (Boyce, 1994c, 1997). In addition, he is coordinator of the Araceae project for the Flora of Thailand, contributing the accounts for the Pothoideae and Monsteroideae. Most of his recent publications deal with the biogeography (Boyce, 1996c), and architecture and growth patterns of *Pothos* (Boyce & Poulsen, 1994) and *P. grandis* (Boyce & Nguyen, 1995, 1996), and miscellaneous papers as well as other genera from southeast Asia including *Amydrium* (Boyce, 1995a), *Bucephalandra* (Boyce, 1995b; Boyce *et al.*, 1995a), *Eminium* (Lobin & Boyce, 1991), *Hapaline* (Boyce, 1996), *Homalomena* (Boyce, 1994b), *Pinellia* Ten. (Boyce, 1988), *Rhaphidophora* (Boyce, 1996b, 2000c), *Schismatoglottis* and *Pycnospatha* (Boyce, 1993b), *Scindapsus* (Boyce, 1993c), and *Steudnera* (Boyce, 1995b). Besides working with Asian genera his studies have also included African genera, namely *Culcasia* (1995g) and the American genera *Anthurium* (Boyce, 1995e) and *Ulearum* (Boyce, 1995f). Boyce was largely responsible for compiling a special issue of *Curtis's Botanical*

*Magazine* that was devoted entirely to Araceae and included genera from Asia, Africa, and America (Boyce, 1995d-i). Many of his individual contributions to this are cited above but he also wrote for this work an introduction to the family Araceae (Boyce, 1995d), Araceae at the herbarium of Kew (Boyce, 1996b), and an article on aroid conservation (Boyce, 1995i) for the special issue. Boyce co-authored an article on aroid cultivation with P. Brewster and R. Wilford (Boyce *et al.*, 1995) and along with Mayo and Bogner he contributed an article on the history of Araceae research (Mayo *et al.*, 1995). Boyce (1996d) also contributed *Arisarum*, *Arum*, *Biarum*, and *Pothos* to *The World of Plants* series. Finally, Boyce is a member of a team (including Mayo and Bogner) who are working on a new understanding of the family at both the supra-family level (Mayo *et al.*, 1995b) and at the suprageneric level (Mayo *et al.*, in press). His intimate knowledge of the Asian Araceae is critical to that effort. Along with Mayo and Bogner, he is an author of *The Genera of Araceae* (Mayo *et al.*, 1997) and he lectured on this subject at the VI International Aroid Conference in Kunming, China (Mayo *et al.*, 1998). Boyce also contributed to a major study dealing with an infrageneric and infrafamiliar phylogeny of subfamily Monsteroideae with Sheh-May Tam as the senior author (Tam *et al.*, 2004).

Miklos Treiber, working at the University of North Carolina at Chapel Hill, did his Ph.D. thesis on a biosystematic study of the *Arisaema triphyllum* complex (Treiber, 1980).

Collette Ntépé-Nyame of the University of Cameroon has described a new species of *Rhektophyllum* (*R. camerunense* Ntépé-Nyame [now *Cercestis*] (Ntépé, 1981). She also wrote a paper, with R. Letouzey in Paris, on the nomenclatural and taxonomic problems with *Culcasia scandens* (Letouzey & Ntépé, 1981). Her most recent contribution is the treatment of the Araceae for the Flore du Cameroun (Ntépé-Nyame, 1988). The treatment, written in French, has 56 plates each with one or more detailed line drawings.

Sue Thompson of the Carnegie Museum published her first paper on the distribution and ecology of *Cyrtosperma chamissonis* Merr. (Thompson, 1982). She has begun a revision of *Xanthosoma* (Thompson, 1984, 1985, 1989) and did her Ph.D. thesis on the systematics and biology of Araceae and Acoraceae of temperate North America (Thompson, 1990). She contributed the treatment of the Araceae for the *Flora of North America* (Thompson, 2000) and another paper detailing the biology of North American Araceae (Thompson, in prep). Thompson

is a member of the Honorary Board of Directors for the International Aroid Society and has also been editor of the *I. A. S. Newsletter*.

Chinese botanists, Wen-yen Lien and Ru-zhi Feng, published a survey of *Arisaema* and *Pinellia* in China (Lien & Feng, 1982). Z. Xie *et al.* (1996) reported on morphological variation within *P. ternata* populations, and Z.-L. Wang introduced a new species of *Sauromatum* from Gaoligong Mountains (Z.-L. Wang & H. Li, 1999). A new species, *Typhonium jinpingense* Z. L. Wang, H. Li & F. H. Bian, is described from Yunna Province with a haploid chromosome number of 10, making it, along with *Anthurium gracile*, the lowest base number in the family (Wang *et al.*, 2002).

Denis Barabé, at the Montreal Botanical Garden, working with different collaborators, made extensive studies of the floral anatomy (Barabé, 1982; Barabé & Chrétien, 1985, 1986; Barabé & Forget, 1988a-b, 1992; Barabé & Labrecque, 1983, 1984, 1985; Barabé *et al.*, 1984, 1985, 1986a, 1987a; Jeune & Barabé, 1998; Poisson & Barabé, 1998) and development (Barabé, 1993, 1994, 1995; Barabé & Bertrand, 1996; Barabé & Jean, 1996; Boubes & Barabé, 1996, 1997; Barabé, D. & C. Lacroix, 2003; Barabé *et al.*, 1986b, 1987b, 1996b, 2003) of various genera and species of Araceae. These studies include a discussion of neotany in the Araceae (Barabé, 1987) and a cladistic analysis of the Calloideae (Barabé & Forget, 1987a). More recently, Barabé investigated homeosis of *Philodendron* (Araceae) (Barabé *et al.*, 2002a, 2002b; Barabé & Lacroix, 1999, 2000), and completed further studies on floral developmental morphology within Araceae (Barabé & Lacroix, 2001a & b, 2002; Barabé *et al.*, 2000, 2002, 2003). Papers have been published describing flowering and pollination of Aroid species, including *Philodendron melinonii* and *P. squamiferum* (Gibernau & Barabé, 2000, 2002), as well as, thermogenesis in several *Philodendron* (Gibernau & Barabé, 2000; Barabé *et al.*, 2002). Collaborating with three other aroid researchers, Barabé studied seed predation in *Philodendron solimoesense* by chalcid wasps (Hymenoptera) (Gibernau *et al.*, 2002), and beetle pollination of Araceae (Gibernau *et al.*, 1999; Gibernau & Barabé, 2003).

The late Mark Moffler, former editor of *Aroideana* and student of *Homalomena*, was working on a revision of the genus *Homalomena* at the time of his death. His published papers deal with the anatomy of *Homalomena* (Moffler, 1983), a description of a new species with Josef Bogner (Moffler & Bogner, 1984), the cold tolerance of Araceae (Moffler, 1980), and on *Anthurium*

*araliifolium* (Moffler, 1981). His partially finished thesis on the genus is being revised by Tom Croat and Richard Wunderlin with assistance from Richard Mansell (Moffler *et al.*, in prep). Richard Wunderlin, University of South Florida, recently published three new taxa of *Homalomena* including *Homalomena moffleriana* Croat to honor the late Mark Moffler (Croat & Wunderlin, 2004).

Farah D. Ghani from Malaysia published a paper on useful Araceae of Peninsular Asia (Ghani, 1983) and one on edible aroids (Ghani, 1984a) that includes keys for the identification of cultivars of *Colocasia esculenta* in Malaysia (Ghani, 1984b).

George R. Haager, currently Director of the Prague Botanical Garden in the Czech Republic has had a long interest in Araceae, collecting in Mexico, Venezuela and Ecuador. He was responsible for collecting *Anthurium sarukhanianum* in Mexico (Croat, 1991a). He has also described other new species from Ecuador (Haager & Jenik, 1984) and Mexico (Haager, 1991).

W. Greuter (Greuter, 1984) produced a revision of *Arum* for the island of Crete in the Mediterranean.

Arie de Graaf, sometimes with J. C. Arends and J. D. Bastmeijer, has published papers on *Cryptocoryne*. Graaf & Arends published on the occurrence of *Cryptocoryne* and *Lagenandra* in Sri Lanka (Graaf, 1987a, 1987b, 1988, 1991; Graaf & Arends, 1986). J. D. Bastmeijer published a series of short papers, each featuring a species of *Cryptocoryne* (Bastmeijer, 1982, 1984, 1986a, 1989, 1991, 1992, 1993, 2002; Bastmeijer & Leenen, 1983; Bastmeijer & Kettner, 1991; Bastmeijer *et al.*, 1984) and along with Arends published on the chromosomes of *Lagenandra* (Arends & Bastmeijer, 1978). He published biographic notes about de Wit and Jacobsen (Bastmeijer, 1986b). Finally Arends and F. M. van der Laan published a paper on the chromosomes of *Lagenandra* (Arends & van der Laan, 1978).

Richard Keating from Southern Illinois University has spent part of the past 15 years working on the vegetative anatomy of the Araceae for Metcalfe & Chalk's *Anatomy of Monocotyledons* (Keating, 2003a). He has presented papers at major meetings that dealt with the anatomical distinction between the Pothoideae and Monsteroideae (Keating, 1980) and with other relationships within

the family (Keating, 1982). Other general papers entitled "Techniques for studying aroid anatomy", "Vegetative anatomical features in the Araceae," "Structural trends in lamina histology in the Araceae", are expected to be published in upcoming issues of *Aroideana*. Keating published a manuscript on collenchyma in Araceae (Keating, 2000), and more recently, one on leaf anatomical characters and their value in understanding morphoclines in the Araceae (Keating, 2003b), as well as manuscripts on the systematic occurrence of raphide crystals in Araceae (2004b) and vegetative anatomical data (2004a).

William N. Carvel has completed an as yet unpublished thesis dealing with the floral anatomy of the Pothoideae and Monsteroideae (Carvell, 1989a, 1989b). Another work worthy of mention is a completed revision of *Stenospermation* for Central America by Alcira Pérez de Gómez (1983), a Venezuelan student from Barquisimeto, who worked under the direction of Tom Croat.

Kerim Alpınar, at the Department of Pharmacy of the University of Istanbul in Turkey and has published a key (with illustrations) to the Turkish species and recognized new taxa as well as reported on the starch and protein content of the Turkish species (Alpınar, 1985). In addition, he has published chromosome information on *Arum* in Turkey (Alpınar, 1987) as well as phytochemistry of *Dracunculus vulgaris* Schott (Alpınar & Meridi, 1987).

Surawit Wannakrairoj at the Department of Horticulture at Kasetsart University in Bangkok, Thailand, a former student of H. Kamemoto at the University of Hawaii, works on a breeding program with *Aglaonema*. His thesis involved studies of *Anthurium* spathes and the inheritance of color, a feature so important to the cut flower industry (Marutani *et al.*, 1988; Wannakrairoj & Kamemoto, 1990a, 1990b).

Long Chun-lin from the Kunming Institute of Botany in China published his first papers on *Amorphophallus* in China in collaboration with Li Heng (Li & Long, 1989a, 1989b). Working with Li Heng, Gu Zhijian and Liu Xianzhang, he produced a cytogeographic study of *Remusatia* (Long *et al.*, 1989) and a study of the karyotypes of *Amorphophallus* from China. A recent paper dealt with ethnobotanical uses of *Amorphophallus* (Long, 1992, 1998). He presented a paper on *Amorphophallus* of China at the VII International Aroid Conference (Long *et al.*, in press). He has been involved with many papers with Li Heng, including the recent study of aroids of the Gaoligong Mountains (Li *et al.*, 1999) and a new

species of *Amorphophallus* (Long & Li, 2000). See also papers discussed under Li Heng.

Z. Y. Zhu (1985) redescribed *Alocasia cucullata* (Lour.) G. Don in Sichuan, China as the "new" genus *Panzhuyuia* with a single species, *P. omeiensis*.

Greg Ruckert, founder of the Australian Area collection and the journal *Area* that features information about tuberous aroids, especially *Arisaema*, has published articles on *Arisaema* and recently participated in the work on the Gaoligong Mountains (Li *et al.*, 1999; Li & Ruckert, 1998).

P. J. Matthews published several papers on taro, including their cultivation (Matthews, 1987), the origins, dispersal and domestication (Matthews, 1990, 1995; Matthews *et al.*, 1992), and on ribosomal and mitochondria DNA variation (Matthews *et al.*, 1992). S. Chandra (1984) published a work on the taro and other edible aroids.

A. G. Panurangan and V. J. Nair (1994), from the Tropical Botanical Garden and Research Institute, Thiruvananthapuram, India and Kew Gardens respectively, published a new species of *Pothos*, *P. keralensis*, from Kerala State in SW India.

Yashica Singh, from the National Botanic Institute in Durban, South Africa in collaboration with A. E. van Wyk and H. Baijnath, has published a guide to identifying members of *Zantedeschia* (Singh *et al.*, 1995). They have also worked on the floral biology of *Z. aethiopica* (Singh *et al.*, 1996a) and on taxonomic notes of the genus (Singh *et al.*, 1996b). These publications form part of a M.Sc. study on the systematics of *Zantedeschia* (Singh, 1996) undertaken by Singh at the University of Pretoria.

Jenn-Che Wang from Taiwan Normal University in Taipei, Taiwan has completed a systematic revision of Taiwanese *Arisaema* (Wang, 1996). The work contains detailed drawings, photographs of spathe and spadix, and pollen micrographs.

Matyas Buzgo did his PhD thesis at the Institute of Systematic Botany at the University of Zurich and now works at the Natural History Museum at the

University of Florida, Gainesville. His thesis dealt with floral development of the Araceae with comparisons with the Alismatales and Acoraceae (Buzgó, 2001). He has also worked with odor production in *Lagenandra* (Buzgó, 1998), with the development of inflorescences of *Pistia*, leaf development in basal monocots (Rudall & Buzgo in press), and molecular systematics of *Arisaema*. His actual studies are on the expression pattern of homeotic genes [responsible for the regulation of other genes, and therefore for development] in Alismatales, a group including Araceae.

Mihaela Antofie at the Institute of Biology at Bucharest University in Romania has done research with micropropagation of several aroid genera, notably *Syngonium* and *Spathiphyllum*. Her thesis entitled “Study of factors involved in morphogenetic potential expression of some in vitro cultured ornamental plant species” (Antofie, 2002). She has worked with peroxidase activity associated with wounding stress in *Syngonium* (Antofie, *et al.* 1999) as well as in vitro development of *Spathiphyllum* (Antofie & Brezeanu, 2003; Antofie, 2004).

Alain Fridlender, at the Université de Provence, Marsailles, France is working with Araceae in the Mediterranean region. Working in a university department entitled *Dynamique et Ressources du Végétal/IUP-ENTES*, his research involves a study of the evolution of some Mediterranean genera belonging to Araceae/Colchicaceae (Fridlender, 1999, 2000a, 2000b). He works with poorly known species, endemism in species of Araceae and polyploidy in Araceae, making use of cytology, flow cytometry, floral biology and molecular phylogeny.

Michael Hesse at the Institute of Botany and Botanical Garden, University of Vienna working with Josef Bogner, H. M. Halbritter and Martina Weber works with pollen of Araceae. Papers dealing with the perigoniata Aroideae: *Zamioculcas*, *Gonatopus* and *Stylochaeton* (Hesse *et al.*, 1998c, 2000b & 2001), have been published, as well as, manuscripts on pollen wall types and stratification (Hesse, 1999, 2000; Hesse *et al.*, 2000a; Weber *et al.*, 1998a, 1999), and roles of pollen in Araceae systematics (Hesse, 2001b, 2002a; Hesse *et al.*, 1998b). Two recent papers deal with zona-aperturate pollen grains of *Proxapertites* with affinity to Araceae (Zetter *et al.*, 2001; Hesse & Zetter, 2001). Other research has been published on the rarity of Araceae pollen (Hesse *et al.*, 1998b), pollen features in



the Arum lilies (Hesse, 2001a), pollen aperture in Lasioideae (Hesse, 2002b), and pollen structure (Hesse, 2003a & b).

Victor Soukup from the University of Cincinnati has been working for a number of years on a broad survey of the Araceae studying the distribution of fatty acids (Nicolaidis *et al.*, 1983; Schmid, *et al.* 1999; Meija & Soukup, 2004). He is continuing this work and needs fresh seeds for some genera. If you are interested please contact him.

Gar W. Rothwell, working with Michelle R. Van Atta, Harvey E. Ballard, Jr. and Ruth A. Stockey, has completed a molecular study involving the Lemnaceae and Araceae using chloroplast trnL-trnF intergenic spacer genes. Rothwell *et al.* (2004) justifies the incorporation of the Lemnaceae into the Araceae.

Jorge Jácome, a graduate of the Universidad Nacional de Colombia in Bogotá, studied the vertical distribution of Araceae on Cabo Corrientes in Chocó Department at the Estación Biológica El Amargal (Jácome, 2000; Jácome *et al.*, in press) and is currently a student at the University of Göttingen in Germany. His studies are also with epiphytes, but now in Bolivia. With Tom Croat he published a paper describing for the first time the inflorescence of *Monstera minima* (Jácome & Croat, 2002 [2003]).

Working with the Jardín Botánico in Bogotá, Jorge collected aroids in order to prepare a treatment of the *Araceae of the Botota Region (Cundinamarca Department, Colombia)* (Jácome & Croat, in prep). The project has been stalled now that he is in graduate school but with the help of Tom Croat he hopes to continue the study. One of the most exciting discoveries during this work was the recollection of *Anthurium metallicum* Linden ex Schott, a beautiful member of Section *Cardiolonchium*, hitherto of unknown origin (Jácome & Croat, in press).

Martha Marcela Mora, a graduate of the Universidad Nacional de Colombia in Bogotá, worked on the Araceae flora of Cabo Corrientes. Working at the Estación Biológica El Amargal she discovered a number of new species of Araceae (Mora & Croat, 2004) vertical distribution of Araceae on Cabo Corrientes in Chocó Department. This work earned her the highest honors at the university for quality of her thesis (2002). The results of her thesis were presented at the VIII International Aroid Conference and will be published in a paper in the

Annals of the Missouri Botanical Garden in 2005. Marcela is currently working on her Master's degree at the Universidad de Porto Rico in Mayaguez and will soon begin a new project the Royal Botanic Garden working with web development of the genus *Philodendron*.

Lynn Hannon, Odesa, Florida, began a revision of *Chlorospatha* in the year 2000 with the encouragement and help of Tom Croat. This exhaustive study is now completed (Croat & Hannon, in press). This revision demonstrates the richness of poorly known Andean genera that show a great increase in the number of species previously undescribed (30 of 70 species are new to science). Lynn's living collection of mostly Ecuadorian species is unparalleled. She has participated in many field trips, mostly in Ecuador, mostly accompanying Tom Croat. She recently published a revision of the species of *Chlorospatha* from Antioquia Department, Colombia (Croat & Hannon, 2004).

Felipe Cardona, at the Universidad de Antioquia has worked on the genus *Spathiphyllum* for Colombia (Cardona, in prep.) and intends to continue his work on *Spathiphyllum* to prepare a much needed new revision of the genus. He has published a new species of *Spathiphyllum* from Colombia and Panama (Croat & Cardona, 2004). His preliminary studies were reported at the VIII International Aroid Conference in St. Louis, and published in the Annals of the Missouri Botanical Garden (Cardona, 2004).

## MISCELLANEOUS DISCIPLINES THAT PLAYED AN IMPORTANT ROLE IN THE HISTORY OF AROID RESEARCH

It is not the intent of this paper to cover all disciplines that have affected our understanding of Araceae. However, some specialized researchers made discoveries that have greatly enhanced our understanding of the taxonomy and evolution of the family.

Papers dealing with fossils, though often individually not important should be mentioned because of their relative importance to the study of evolution of Araceae. Among them are papers by Madison & Tiffney (1976), Bogner (1976c), Gregor & Bogner (1984, 1989), Dilcher & Daghljan (1977), and (Stockey *et al.*, 1997).

In the field of vegetative and floral anatomy of aroids, the works of P. van Tieghem (1867, 1872, 1885), H. Solereder (1919), and Solereder & F. J. Meyer (1928) are noteworthy, as are those of M. Lierau (1887, 1888) on roots, M. Dalitzsch (1886) on leaf anatomy, and E. Daumann (1931) on nectar production. Engler, no doubt, built on these extensive anatomical studies and more recent morphological studies of floral anatomy by Eyde *et al.* (1967), Carvell, Barabé, and Blanc (see above) and studies with fruits and seeds (Martius, 1831; Krishnamurthi & Geetha, 1986; Kulkarni *et al.*, 1990; Seubert, 1993) have also been important in helping to define relationships in the family. [See also the discussion of the important anatomical work by J. C. French.]

Developmental and embryological studies have been comprehensive. Embryological studies have been made by D. H. Campbell (1900, 1903, 1912) and F. J. Jüssen (1929), and systematically important aspects of embryology were reviewed by Grayum (1985, 1986a). James Gow (1908) made developmental studies on a variety of genera, followed by a paper attempting to define phylogeny in the Araceae (Gow, 1913a, 1913b) [see also Barabé, Blanc, and Ray above]. Other studies of growth behavior have been made on *Philodendron* (Ritterbusch, 1971) and *Symplocarpus* and *Lysichiton* (Rosendahl, 1911). Hans-Jürgen Tillich, from Germany, has carried out extensive surveys of the structure and growth behavior of seedlings of Araceae as a part of his broader survey (Tillich, 1985). Also, M. Möbius (1936) published a brief review of vegetative reproduction.

Molecular studies have been done on the economically useful genera *Colocasia* and *Alocasia* by H. Yoshino (1975, 1994, 1995, in press) in Japan and China. (See also section above on James French.) Papers critical to the understanding of the evolution of the Araceae are molecular studies of *rbcL* in the Liliiflorae (Chase & Albert, 1995) and among all monocots (Duvall *et al.*, 1993). A recent molecular study appears to establish the Lemnaceae along with the genus *Pistia* to form a monophyletic group within the Araceae (Stockey *et al.*, 1997).

There have been numerous studies on chromosomes of Araceae. In England, C. J. Marchant conducted an important series of cytological studies throughout much of the 1970's (Marchant, 1970, 1971a, 1971b, 1972, 1973, 1974). His section-by-section treatment and discussion of cytology is one of the earliest attempts to understand the Araceae cytologically. His cytological work was preceded by others, who though not dealing specifically with Araceae, did a great deal of cytological work with the Araceae. Among these researchers are G.

E. Jones in the United States (Jones, 1957), P. Pfitzer (Pfitzer, 1957) in Germany, and several other cytologists, especially in India. Principal among the Indian cytologists is A. K. Sharma and his collaborators. Their papers deal with a study of karyotypes (Sharma & Das, 1954), the cytological evolution of *Aglaonema* and *Richardia* [= *Zantedeschia*] (Sharma & Datta, 1961), a cytological study on *Philodendron* and *Monstera* (Sharma & Mukhopadhyay, 1964), on *Arisaema* and *Typhonium* (Sharma & Mukhopadhyay, 1965) and on eight genera in five tribes (Sharma & Bhattacharya, 1968). Other cytological work was carried out by A. Mookerjea who attempted to trace the evolution of a number of genera of Araceae (Mookerjea, 1955). Both K. Ramachandran (1977, 1978) and K. S. Patil (Patil & Dixit, 1995) did studies on Indian Araceae.

Reviews of the cytology of the Araceae were made by C. J. Marchant (1970, 1971a, 1971b, 1972, 1973, 1974), and the cytology of *Anthurium* has been recently summarized by Sheffer (Sheffer & Croat, 1983) and for the whole family by Gitte Petersen of Copenhagen. Petersen did a thorough review of the cytology of the Araceae for her Masters thesis as well as in other subsequent cytological work (Petersen, 1989, 1993a, 1993b; Petersen, unpublished). Kai Larsen, at the University of Aarhus, did a revision of the cytology of the aroids of Thailand (Larsen, 1969).

Michael H. Grayum has recently reviewed the palynology of the Araceae (Grayum, 1984, 1990). In addition to Grayum's study there have been other major and some minor palynological studies on the Araceae. One of the first thorough studies that preceded Grayum was a light microscopic study of Araceae pollen by the late G. Thanikaimoni (1969) of India. Ohashi *et al.* (1983; J. Murata & Ohashi, 1984) reviewed the pollen morphology of *Arisaema*. M. Zavada made an extensive comparative study on aroid pollen, especially involving evolutionary trends of apertures and wall structures (Zavada, 1983). A review of the pollen of *Amorphophallus* and *Pseudodracontium* was made by van der Ham, Hettterscheid and van Heuven (Ham *et al.*, 1998). Daniel Beath, from England, has a principal interest in pollination of Araceae and has completed a study on *Amorphophallus* in Ghana (Beath, 1996), and on beetle pollination in *Dieffenbachia longispatha* (Beath, 1999). Current work on palynology is being carried out by V. F. Tarasevich at the Komarov Botanical Institute. She has published an SEM study of 34 species of *Anthurium* (Tarasevich, 1989). Micheal Hesse has also been a major contributor to pollen research within the Araceae (refer to section on Micheal Hesse).

Chemical aspects of Araceae have been reviewed by Hegnauer (Hegnauer, 1963, 1986, 1987) and more recently by Dring and his associates at the Jodrell Laboratory at Kew (Dring *et al.*, 1995).

Studies on pollination biology of Araceae are numerous and have been reviewed elsewhere (Grayum, 1986c, 1990; Bay 1995). K. Dormer (1960) wrote on pollination in *Arum*. Y. Mori and H. Okada (in press) reported on reproductive biology and pollen flow of *Furtadoa*. Most have dealt with the physiological phenomenon of thermogenesis (Walker *et al.*, 1983) and only indirectly with pollination (Uemura *et al.*, 1993). No attempt will be made here to review all of the literature on pollination biology of Araceae but some of the more recent and thus not previously reviewed papers dealing with the subject will be mentioned here. A recent paper (Patt *et al.*, 1995) discusses the brood-site-based pollination system of *Peltandra virginica* in eastern North America. The work also serves as the debut of Jim French, one of the coauthors, into work with pollination systems. Pollination strategies were studied in Brazilian species of *Philodendron* (Gottsberger & Amaral, 1984).

A major review work on P-type sieve-element plastids of all the Arales (Behnke, 1995) provides new evidence for the inter-relationship of the Araceae to other closely related monocots and for the subgeneric classification of the family.

Finally, other general papers dealing with phylogeny are critical to the understanding of the evolution and general placement of the Araceae among the monocotyledons. Some of these are: Takhtajan (1969, 1980, 1997); Thorne (1968, 1976, 1983); Hutchinson (1973); Cronquist (1981); and Dahlgren & Rasmussen (1983).

#### MISCELLANEOUS PAPERS MOSTLY DEALING WITH SPECIFIC GENERA

In any review of this kind there are always some research publications or individual horticultural treatments, that though individually worthy of comment, are not cited in any of the above commentary. Generally these are contributions by persons not considered to have played an important role in the history of aroid systematics but whose contributions may be of special interest to those seeking information about a particular genus. These publications will be cited here and

will be referenced by genus in alphabetical order. They include: *Aglaonema* (Brown, 1895a; Craig, 1988; Jervis, 1978, 1980); *Alocasia* (Brown, 1882b, 1884b, 1884c, 1885a, 1887, 1894, 1895b, 1898; Burnett, 1984; Chai, 1975a; D'Ancona, 1885; Hooker, 1865; Houtte, 1863; Linden, 1865, 1882a; Pijl, 1933; Linden & Rodigas, 1886a, 1886c, 1887); *Amorphophallus* (Akiya, 1933; Allen, 1998); Brummit, 1978, 1983; Camp, 1937; Carrière, 1871; Dakkus, 1924, 1957; Everett, 1937; Giordano, 1999; Hodge, 1962; Houtte, 1863b; Larsen & Larsen, 1974; Lemaire, 1860, 1865; Misra *et al.* 2002; Phillips, 1988; Pijl, 1937; Regel, 1875; Reijnvaan, 1924, Stout, 1937; S. Singh & Gadgil, 1995); *Anchomanes* (Tchiakpè, 1979); *Anthurium* (Barahona Carvajal, 1978; Dressler, 1978, 1980; Sheridan, 1994); *Anubias* (Chang *et al.*, 1993, Rada & Jaimez, 1992; Sheridan, 1994); *Arisaema* (Alexander, 1959; Barnes, 1934, 1936, 1940, 1946; Barnes & Fischer, 1936b; Bierzychudek, 1982; Chadwell, 1994; Chu, 1979; Clay, 1993; Dieringer & L. Cabrera R., 2000); Franchet & Savatier, 1878; Fu, 1990; George & Stuckey, 1989; Glattstein, 1989a, 1989b; Gouda & G. Gusman, 1999; Grey-Wilson, 1992; Grimshaw, 1992; Gusman, 1992, 1993, 1994a, 1994b, 1995, 1997a-f, 1998a-c, 1999, 2000; L. Gusman & G. Gusman, 1997, 1998, 1999; Hammond, 1985; J. Harris, 1915; Hillstrom, 1986; Kao, 1989; Kinoshita, 1994; Ko & Kim, 1985; Ko *et al.*, 1987, 1990a, 1990b, 1993; Lovett & Cavers, 1982; G. Maekawa, 1924, 1936; McClements, 1997, 2000; Murata, 1956, 1962; Nava, 1994; Nelson, C., 1999; Oh *et al.*, 1990; Ohba, 1962; Ohno & Tsukada, 1986; Oliver, 1871; Raymond, 1949; Richardson & Clay, 1993a, 1993b; Schmidt (2002); Sealy, 1939a, 1939b; Shaffner, 1922; Stilwell, 2000; Takasu, 1987; Taekeda, 1906; Treiber, 1980; Wada *et al.*, 1993); Wright, 1920; Wurdak, 1983; Yadav *et al.*, 1997; Zhu, 1982; *Arisarum* (Galil, 1978; Mossi, 1959); *Arum* (Aked, 1989; Gonzales-Patino, 1977; Hooker, 1828; Hruby, 1912; Upshaw, 1998; Méndez & Obeso, 1993, Ventenat, 1800); *Caladium* (Lemaire, 1863); *Calla* (Dudley, 1937; Lehmann & Sattler, 1992; Topic & Ilijanic, 1989); Genaust, 1999; *Colocasia* (Barrett, 1910; Cook, 1910; Haudricourt, 1941; Hill, 1939; Harris *et al.*, 1992; Hirai *et al.*, 1989; Hodge, 1954b; Linden & Rodigas, 1886b; Plarre, 1995; Plucknett, 1983; Sunnell & Arditti, 1983; Sastrapradia & Rijanti, 1972; Tanimoto, 1990; Wang, 1982; Whitney *et al.*, 1939); *Cryptocoryne* (Bastmeijer, 2000; Benl, 1960; Bouwmeester & Hoogendoorn, 1966; Davis & Kane, 1995; Dötsch, 1985, 1986, 2001; de Graf, 1980; Eichner, 2001; Hendriks, 1981; Hertel, 1985; Hertel & Mühlberg, 1994; Jones *et al.*, 1980; Kane *et al.*, 1990; Kasselman, 1986; Koorders, 1981a; Korthaus, 1980; Machlin, 1997; Mansor, 1991; Möhlmann, 1989; Mühlberg, 1980 [mostly *Cryptocoryne*]; Ørgaard & Jacobsen, 1998 [also *Lagenandra*]; Reumer, 1984; Schulze, 1971a-d; Watts,

1995, Wendt, 1954; *Cyrtosperma* (Linden & Brown, 1892); *Epipremnum* (Hemsley, 1904); *Gymnostachys* (Shelton, 1980); *Homalomena* (Brown, 1884a, 1885a, 1885b; Chai, 1975b); *Hydrosme* (Troll, 1951); *Lasia* (Hambali & Sizemore, 1997); *Lysichiton* (Bowerman, 1933; Hiratsuka *et al.*, 1995); Hultén, 1932, 1934; Hultén & St. John, 1956; Turesson, 1916; *Monstera* (Bloch, 1946; Haydon & Shaw, 1991); *Montrichardia* (Crüger, 1854); *Nephtytis* (Alexander, 1955); *Orontium* (Gear, 1966; Klotz, 1991, 1992); *Peltandra* (Barkley, 1944); *Philodendron* (Barahona Carvajal, 1978; Cutak, 1962; Grau, 1983; Kramer, 1974; Pabst, 1980; Vas *et al.*, 1984; Waterbury, 1983); *Pinellia* (Rugh, 1990); *Piptospatha* (Brown, 1879, 1910); *Pistia* (Aliotta *et al.*, 1992; Chillers, 1991; Coert, 1934; Nelson, 1993); *Podolasia* (Brown, 1882c); *Pothos* (Burt, 1936; Linden & André, 1880); *Scindapsus* (Carrière, 1884); *Sauromatum* (Meeuse, 1966); *Schismatoglottis* (Brown, 1884a; Linden, 1881, 1882); *Spathicarpa* (Troll, 1928, 1932); *Spathiphyllum* (Regel, 1870); *Symplocarpus* (Berthold & Siedow, 1993; Case, 1992; Shufeldt, 1918; Small, 1959; Voss, 1964); *Taccarum* (Arcangeli, 1879a, 1879b); *Typhonium* (Banerji, 1947; van Steenis, 1948b; Turrill, 1951; Zhu, 1982); *Xanthosoma* (Okeke, 1992; Quynh & Uyen, 1987); *Zantedeschia* (Yao *et al.*, 1994), and *Zomicarpella* (Brown, 1881).

#### OTHER SPECIAL GENERAL WORKS DEALING WITH ARACEAE

Many general works have already been cited that are general in nature but which have dealt, at least in part, with Araceae. These include all the general floristic works and even large monographic accounts such as *Das Pflanzenreich* and *Pflanzenfamilien* (cited above under Engler) but there are also many general works, both taxonomic and ecological, in which Araceae are included. These can be important sources of information for the family. Among these works are standard works (some cited elsewhere in this paper) describing broad scale systems of classification. These include Engler's *Syllabus der Pflanzenfamilien* (Melchior, 1964), as well as the classification systems by J. Hutchinson (Hutchinson, 1934, 1959), A. Lemée (Lemée, 1941), G. H. M. Lawrence, (Lawrence, 1964), A. B. Rendle (Rendle, 1930); A. Cronquist (1968), R. M. J. Dahlgren and H. J. Clifford (1982; Dahlgren *et al.*, 1985).

Other general works that discuss important aspects of Araceae are those dealing with phytogeography (Willis, 1949), fruit dispersal (van der Pijl, 1969), ethnobotany (Duke & Vasquez, 1994), pollination systems (Faegri & van der Pijl, 1966), growth habits of monocotyledons (Holttum, 1955), and rheophytic plants

(van Steenis, 1981, 1987). A few standard reference works dealing with horticultural plants are also important references. These include the *Manual of Cultivated Plants* (Bailey, 1949), *The Standard Cyclopedia of Horticulture* (Bailey, 1963), *Hortus Third* (Bailey & Bailey, 1976), *Exotica 3* (Graf, 1963), *Exotica 4* (Graf, 1982), *Exotica International* (Graf, 1985), *Tropica* (Graf, 1986) and *Hortica* (Graf, 1992), *The New York Botanical Garden Illustrated Encyclopedia of Horticulture* (Everett, 1980-1982), *The New Royal Horticultural Society Dictionary of Gardening* (Huxley, 1992), *European Garden Flora* (Walters *et al.*, 1984); *The RHS Encyclopedia of House Plants* (Beckett, 1987), *Index of Garden Plants* (Griffiths, 1994), *Pareys Blumengärtnerei* (Encke, 1958), and *In Gardens of Hawaii* (Neal, 1965).

A few additional references are, in effect dictionaries that give vital statistics, and in some cases a list of all genera for each family. Among the earliest complete dictionary of this type was that by Ernst Ender (1864) who published his *Index Aroidearum* with an introduction by Karl Koch. In *Genera Siphonogarum* genera are arranged according to the Englerian system (Dalla Torre & Harms, 1900). This work gives details about the taxonomy of the family and is directly associated with a separate concise dictionary (Dalla Torre & Harms, 1958). In the *Plant Book* (Mabberley, 1987) genera are arranged alphabetically.

An important reference source for learning about floristic projects that might now, or in the future, deal with Araceae floras is *Floristic Inventory of Tropical Countries* by D. G. Campbell and H. D. Hammond (1989).

## PRESENT FOCUS ON AROID RESEARCH

The current focus of research with Araceae is to a great extent covered by the past history since many of the participants are doing similar research and continue to be active. Simon Mayo, Josef Bogner, and Peter Boyce have released their long awaited book, *The Genera of Araceae* (1997) published by Kew. Simon Mayo continues his efforts in Brazil along with several Brazilian collaborators. Mayo is working on a checklist for the Araceae of Brazil and in collaboration with Tom Croat will begin a study of *Philodendron*, which will involve the production of a thorough web-based analysis of the entire genus which will allow the public to have access and determine plants by means of a multi-access key. Tom Croat has finished a revision of *Dieffenbachia* of Central America and a preliminary key to the species of South America. Work continues on the revision of *Rhodospatha*



and a revision of *Homalomena* sect. *Curmeria* and a revision of *Anthurium* sect. *Porphyrochitonium*. With Monica Carlsen, University of Missouri, St. Louis, he has completed a revision of *Anthurium* sect. *Semaephyllium*. He also continues to work with floristic projects in South America, especially with Dorothy Bay on the Araceae of Bajo Calima, and the Araceae of the Guianas. One of the largest commitments is the Araceae for the Flora of Ecuador and fieldwork for the past five years has concentrated there. Local Ecuadorian aroid florulas being completed are the Flora of Lita-San Lorenzo (Esmeraldas), Flora of Shell-Mera (Pastaza), Flora of Parque Nacional Sangay (Tungurahua & Morona-Santiago) and the Flora of Cordillera del Condor (Zamora-Chinchipec).

Alistair Hay, Peter Boyce, Wilbert Hetterscheid, and others on the Flora Malesiana team continue to work toward finishing that major Asian project, now due to be completed in the year 2000. Hay is also responsible for organizing an aroid conference in Sydney in 1989. Hetterscheid works independently on his revision of Asiatic *Amorphophallus*, with S. Ittenbach on the African *Amorphophallus* species (Ittenbach, 2003), and with Ittenbach and Bogner on the *Amorphophallus* species from Madagascar. Jin Murata spends a lot of time in China working on a revision of *Arisaema* for that region as well as for the Flora Malesiana region. He is also undertaking molecular studies on all genera he can acquire. Li Heng is working on a revision of the Araceae treatment for the Flora of China to be included in the English version of the flora, a project being done in part with collaboration by the Missouri Botanical Garden. Li also was responsible for organizing the VI International Aroid Conference held in Kunming, China in late June 1995. The field of Araceae research is attracting new researchers in both Latin America and in Asia.

A large group of researchers, though perhaps having a long-standing interest in Araceae, began publishing articles regarding Araceae in the present decade and some are only beginning their studies. Matyas Buzgó, from the Botanical Garden and Institute for Systematic Botany at the University of Zürich has studied floral development in Araceae, especially *Pistia* (Buzgó, 1994) and *Lagenandra*. A recent paper deals with odor differentiation in *Lagenandra* (Buzgó, 1998).

A small group of researchers in the Department of Horticulture at the University of Hawaii continues work begun by H. Kamemoto with *Anthurium*. Most of the work, carried out under the supervision of Adelheid R. Kuehnle, deals

with aspects of plant breeding, morphology and embryology. Tracie K. Matsumoto, a student of Kuehnle, did her thesis on the embryology of *Anthurium* (Matsumoto, 1994) and has subsequently published other papers dealing with the origin of somatic embryos (Matsumoto *et al.*, 1996), the improvements of observing plant structures with light microscopy (Matsumoto *et al.*, 1995), and on micropropagation of anthuriums (Matsumoto & Kuehnle, 1996). Nuttha Kuanprasert works on fragrance of *Anthurium* species and hybrids (Kuanprasert & Kuehnle, 1995, 1999).

Others who have been working with Araceae are Marcus Nadruz (Rio de Janeiro Botanical Garden), who has recently published two new species of *Anthurium* from the southeast region of Brazil (Nadruz & de S. Leoni, 2004), Shrirang Ramchadra Yadav, from Shivaji University, Gladys Benevides, and Jimena Rodríguez de Salvador. Benevides did her thesis on a study of the Araceae of the 'La Favorita' Biological Reserve in Pichincha Province (Benevides & Ordoñez, 1993). She is continuing her studies with Araceae in other parts of Ecuador. Ileana Arias Grande, working at the botanical garden in Havana, Cuba has a strong interest in Cuban Araceae (Arias Grande, 1992, 1994). Shrirang Ramchandra Yadav, formerly of Goa University in India and now at Shivaji University in Kolapur, India, works on the Araceae of western Ghats (Yadav *et al.*, 1993). He presented a paper at the VI International Aroid Conference in Kunming (Yadav, 1998). He recently published a flora of the Kolhapur District in Maharashtra State, coauthored by M. M. Sardesai (also from Shivaji University) (Yadav & Sardesai, 2002). The flora contains 23 native species as well as a number of introduced species.

Two Brazilian botanists, E.L.M. Catharino and A.R.R. Olaio (Sao Paulo) have published jointly, describing a new species of *Anthurium* (Catharino & Olaio, 1990) and in the preparation of the Araceae treatment for Carozza Island in the Atlantic Ocean off the coast of Sao Paulo State (Olaio & Catharino, 1991).

Elke Seubert conducted a thorough survey of fruits and seeds of the Araceae and proposed a novel system of classification based on that information (Seubert, 1993). Her book, "Die Samen der Araceen" has a wealth of information about fruits and especially seed and contains excellent line drawings. To summarize her work, her observations are divided into five categories: (1) flower characteristics; (2) vegetative characteristics; (3) seed characteristics: seedcoat; (4) seed characteristics: endosperm and embryo; and (5) location of crystals. Each

category is further subdivided into four or five features. Diagrams are presented with the use of colored lines denoting tribes and subfamilies possessing each feature. A review is planned by Josef Bogner. Seubert also studied the distribution and frequency of sclereids within aerial-roots, leaf sheaths, petioles, blades, spadices, and flowers in Araceae (Seubert, 1997).

Elizabeth Widjaja, working at the Bogor Botanical Garden herbarium in Indonesia did her graduate work in England on the genus *Amorphophallus*. Sunu [monomial], a student of Elizabeth A. Widjaja in Bogor, Indonesia, is working on a revision of *Anadendrum*.

Mikhail Serebryanyi, Moscow Main Botanical Gardens, has a principal interest in the Araceae of Vietnam, especially *Pothos* and *Pseudodracontium*. He has prepared a revision of the latter (Serebryanyi, 1995). His first paper dealing with Araceae dealt with pigmentation in new leaves of *Anubias* (Serebryanyi & Filimonove, 1990). During his fieldwork in Vietnam he discovered new species, some of which have been published (Serebryanyi, 1991; Hetterscheid & Serebryanyi, 1994). Serebryanyi, in collaboration with other computer staff at the Moscow Main Botanical Garden, has developed a computerized database for Araceae nomenclature. He organized the very successful IV International Botanical Congress in Moscow in August 1992.

Wilbert Hetterscheid began his career at the University of Utrecht, and then worked for the Vaste Keurings Commissie in Almeer. One of his major botanical connections is at the Leiden Botanical Garden where much of his living collection is housed. He is working on a revision of the Asian species of the large and complex genus *Amorphophallus* of Asia, and he has been successful in bringing many of the species into cultivation, an essential task since herbarium material of these huge plants is notoriously poorly prepared. With S. Ittenbach (Hetterscheid & Ittenbach, 1996), many species of *Amorphophallus* from Asia and Africa were described and illustrated. Hetterscheid estimates that there are a total of 200 species in the genus. He has already published a considerable number of new species, 52 to date (Hetterscheid, 1991, 1992, 1994a, 1994b, 2003; Hetterscheid & Sarker, 1996; Hetterscheid & Serebryanyi, 1994; Hetterscheid & R. W. J. M. Van der Ham, 2001; Hetterscheid *et al.*, 1994, 1996, 1999). With the help of Ching-I Peng from the Academia Sinica in Taipei, he revised the *Amorphophallus* of Taiwan (Hetterscheid & Peng, 1995), and with S. R. Yadav and K. S. Patil (Hetterscheid *et al.*, 1994) he worked on members of

*Amorphophallus* section *Raphiophallus*. With D. DeSarker (1997) he looked at the cytological details of *Amorphophallus margaritifera*, and with Raymond W.J.M. Van der Ham in a textbook called *Pollen and Spores: Morphology and Biology* on the exine pollen structure and taxonomy of *Amorphophallus* (Van der Ham, 2000). A major participant in the Araceae treatment for the Flora Malesiana, Wilbert Hetterscheid is the European coordinator for the project headquartered in Leiden. He will contribute *Amorphophallus* to the flora project. As a part of this project he was a coauthor of the checklist and bibliography for the Flora Malesiana region (Hay *et al.*, 1995, 1995a). A recent paper profiled *Filarum manserichensis* (Hetterscheid & Sizemore, 1997) and another deals with the odor presentation of *Amorphophallus* and *Pseudodracontium* (Kite & Hetterscheid, 1997) and with P.C. Boyce (2000) reclassified *Sauromatum* to *Typhonium*. Wilbert also made significant contributions to the recently published *Amorphophallus titanum* monograph (Barthlott & Lobin, 1998). Though most of his activities involve Asian species he is also interested in tuberous species from the neotropics and has described two species of the tribe Spathicarpeae from Bolivia (“Hetterscheid *et al.* 2003).

Larry Klotz, though not otherwise known as an aroid researcher, made an interesting study of *Orontium aquaticum* (Klotz, 1991, 1992).

A. Lourteig (1990), at the Paris Herbarium, has attempted to typify some of the Araceae depicted in the illustrations done by Charles Plumier (1755-1760).

Guy Gusman, of the Universite Libre de Bruxelles, has emerged as a leading specialist on *Arisaema*. He has published new species of *Arisaema* from China (1999) and Thailand (2001). He has also published on *Arisaema* sections Tortuosa (1993, 1994), *Arisaema* (1994), Trisecta (1995) and Sinarisaema (1999). He has been interested in the messy state of *Arisaema erubescens/consanguineum* and found that Wallich's *Arisaema erubescens* was indeed a different species recently rediscovered at high altitude in Nepal. Guy has also straightened out a complex problem with Mexican species of *Arisaema* (2000). With his wife Liliane, he has published papers on an *Arisaema* hybrid in Meghalaya (1997), on Aroids in Arunachal - the Country of Doini Pollo - (1998) and on a form of *Arisaema concinnum* discovered in NEFA, India (1999). He has recently published manuscripts on the intraspecific variation of *Arisaema speciosum* (Gusman, 2003a), and *Arisaema fimbriatum* (Gusman, 2003b) and published new species from Vietnam (Gusman, G. & V. D. Nguyen.

2002).

Duangchai Sookchaloem (nee Sriboonma), who completed her graduate work under the direction of Jin Murata in Tokyo, works at the Forestry Herbarium at the Royal Forest Department in Bangkok, Thailand. She has revised *Typhonium* with Jin Murata and K. Iwatsuki (Sriboonma *et al.*, 1993; Sookchaloem, 1994). Her work involved molecular studies with restriction site analysis of chloroplast DNA (Sriboonma *et al.*, 1993).

Guanghua Zhu, a student of Tom Croat, completed a revision of *Dracontium* for his Ph.D. study (1994b, 1995b). He has published a new species (Zhu, 1995a) and several papers on the nomenclature of *Dracontium* (Zhu, 1994a, 1996; Zhu & Grayum, 1995) as a step toward the publication of his monograph (Zhu, 1997). His interests continue with the New World Lasioideae, especially *Urospatha* Schott and *Montrichardia* Crueg. Zhu has been instrumental in designing and establishing the International Aroid Society web site that is associated with the Missouri Botanical Garden's web site.

Nguyen Van Dzu (Institute of Ecology and Biological Resources, Hanoi, Vietnam) is working on the Araceae of Vietnam (Nguyen, 1994). Several of his recent papers report new records for Vietnam (Nguyen, 1998a, 1998b, 1999, 2000). With Peter Boyce, he published a paper on *Pothos grandis* (Boyce & Nguyen, 1995) and a new revision of *Amydrium* that includes two new species (Nguyen & Boyce, 1999b). He has also worked with Tom Croat describing a new species of *Typhonium* (Nguyen & Croat, 1997) and with W.L.A. Hettterscheid describing a new species of *Amorphophallus* (Nguyen & Hettterscheid, in press).

Dorothy Bay (Missouri Southern State College), a former student of Tom Croat, prepared a floristic survey of a species-rich site along the coast of western Colombia at Bajo Calima (see above). This massive work, with complete descriptions of over 100 species (a large percentage of them being new to science), will be published in the Annals of the Missouri Botanical Garden.

Jenn-Che Wang from National Taiwan Normal University in Taipei has completed an excellent study of the Taiwanese *Arisaema* (Wang, 1992, 1996). Also at National Taiwan Normal University, T.C. Huang has described a new species of *Arisaema* (Huang & Wu, 1997).

Jimena Rodríguez de Salvador has worked in Ecuador on the Araceae of the ENDESA Biological Reserve (Pichincha Province). (Rodríguez, 1987, 1989; Croat & Rodríguez, 1995). Despite being a region frequented by Sodiro, a high percentage of the flora proved to be new to science.

Frieda Billiet, of the National Botanical Gardens in Brussels and in charge of the living collections there, has collected in French Guiana and elsewhere. She has long been devoted to the Araceae and made her publication debut with Araceae in *Curtis's Botanical Magazine* (Billiet, 1996) with a discussion of *Philodendron* and a redescription of *P. billietiae* Croat (see Croat, 1995a).

Stephan Ittenbach from the University of Bonn in Germany, working under the guidance of Wolfram Lobin, did his Ph.D. dissertation on African *Amorphophallus* (Ittenbach, 1997, 2003). Ittenbach published new species and subspecies of African *Amorphophallus* with Lobin (Ittenbach & Lobin, 1997) and contributed to the *Amorphophallus titanum* monograph mentioned below. Lobin has published a new species of *Eminium* in the Near East with P. Boyce (Lobin & Boyce, 1991) and recently edited an extensive monograph of *Amorphophallus titanum* with W. Barthlott (Barthlott & Lobin, 1998).

Bruce Hoffman studied aerial root fiber products in Guayana made from *Heteropsis flexuosa* for his M.S. Thesis at Florida International University (Hoffman, 1997).

Brett E. Serviss, with the assistance of Sidney T. McDaniel and Charles T. Bryson, has studied *Alocasia*, *Colocais*, and *Xanthosoma* in the southeastern part of the United States (Serviss *et al.*, 2000).

In Brazil, a number of aroid researchers have established themselves and this bodes well for the future of Araceae studies in that country. Simon Mayo has played a critical role in coordinating and promoting these studies (Mayo & Nadruz, 1992).

Marcus Nadruz Coelho began working on aroids in 1986 at the suggestion of Dr. Graziela Barroso, who worked on Brazilian aroid taxonomy in the 1950s and 1960s. Marcus, based at the Jardim Botânico in Rio de Janeiro has worked with various aroid projects (Nadruz-Coelho & Mayo, 1998) and has played an important role in stimulating and supporting other workers in Brazil. His Masters

thesis, supervised by Dr. barroso, was undertaken at the Universidade Federal do Rio de Janeiro--Museu Nacional and was a study of the *Philodendron* species of the montane Atlantic Forest of Macaé de Cima in Rio de Janeiro state (Nadruz-Coelho, 1995; 2000). This resulted in the recognition of 5 new species (Nadruz Coelho & Mayo, 1999). He is now working on his Ph.D. thesis (Universidade Federal do Rio Grande do Sul, Porto Alegre), which is a revision of *Philodendron* subgenus *Pteromischum* of Brazil. He also published the Araceae for the Flora Fanerogâmica da Reserva do Parque Estual das Fontes do Ipiranga in São Paulo State (Nadruz-Coelho, 2000). Since 1992 he has been organizing the annual Araceae Specialists Workshop at the Brazilian National Botanical Congress and has a focal role in the Brazilian aroider network. Nadruz most recently has discovered a new species from Brazil (Nadruz & Sakuragui, 2000; Nadruz & Mayo, 2000).

Eduardo Gonçalves completed his Masters thesis at the Universidade de Brasilia on the Araceae from the Brazilian Federal District (Gonçalves, 1997) and has worked extensively with the Araceae of Central Brazil where he has discovered new species of *Philodendron* (Gonçalves, 1997; Gonçalves, 2000b; Gonçalves & Mayo, 2000; Gonçalves & Bogner, 2004). He has conducted a study of the biogeography of the aroids of Central Brazil (Gonçalves, in press) and studied the rare genus *Gearum* along with Josef Bogner (Bogner & Gonçalves, 1999). He has also photographed, redescribed, and collected the rare species *Anthurium mourae* (Gonçalves, 2001). For his Ph.D. thesis, at the Universidade de São Paulo, he has conducted a phylogenetic analysis of the tribe *Spathicarpeae*, together with a revision of the tribe and studies on morphology of flowers, evolution and biogeography of the tribe (Gonçalves, 2002). Independently of these projects, he has studied the petiolar anatomy (patterns of distribution of collenchyma) in the whole family Araceae (Gonçalves *et al.*, in press) and has become very knowledgeable with flora of the Amazon basin (Gonçalves, 1999; Gonçalves, 2000a; Gonçalves, in press) with special emphasis on *Xanthosoma*. He plans to finish a revision of *Xanthosoma* for Brazil and is working on a revision of *Dieffenbachia* of Brazil with Tom Croat. Gonçalves has also collaborated in a study on the economic uses of *Heteropsis flexuosa* in Brazil (Queiroz *et al.*, 2001). Recent papers include one describing a new *Anthurium* and a new *Gorgonidium* with Josef Bogner (Bogner & Gonçalves, 2002), one describing two new species in the tribe *Spathicarpeae* with Wilbert Hetterscheid and Pierre Ibisch (Hetterscheid *et al.*, in press), one describing two new species of *Philodendron* subgenus *Meconostigma* (Gonçalves & Salviani, in press), one describing new

species of different Brazilian genera (Gonçalves, 2004), a paper describing a new species of *Asterostigma* and two new combinations in *Gorgonidium* as well as one redefining *Taccarum warmingii* Engl. He is also finishing a revision of two small and exclusively Brazilian genera: *Zomicarpa* and *Dracontioides*. Finally, he is preparing a study of the distribution of aroids in regions of Cerrado vegetation, with the help of Carolyn E.B. Proenca and Luiz Guimaraes, and making use of multivariate analysis to define the patterns of distribution.

Cassia Sakuragui is the first Brazilian botanist of recent times to have been awarded her Ph.D. (University of São Paulo, 1999) on Araceae systematics. She began working on aroids in the early 1990s, and went on to carry out a survey of the aroids on the montane (Cadeira do Espinhaço) vegetation of Minas Gerais State for her Masters thesis (University of São Paulo, Sakuragui, 1994) which resulted in the recognition of several new species of *Philodendron* and *Anthurium* (e.g. Sakuragui & Mayo, 1997; Sakuragui & Mayo, 1999). Her Ph.D. thesis was on the taxonomy and phylogeny of *Philodendron* subgenus, *Phildoendron* sect. *Calostigma* (Sakuragui, 1998; Sakuragui, in press), during which she carried out a pioneer molecular systematic study on a sample of species of the genus. She continues with her aroid research at the Univesidade de Maringá in the state of Paraná, describing two new species of *Philodendron* (Kakuragui, 2000). She has interest in other groups of Araceae, such as the Monsteroideae, and along with Peter Boyce and Josef Bogner has made some notes on *Alloschemone* (Boyce *et al.*, 2000). She has also worked on some small floras (Sakuragui, 2000; Sakuragui, in prep.); and general comments on cultivated aroids (Sakuragui, in press). A recent paper on the nomenclature and taxonomy of *Philodendron hastatum* K. Koch & Sello is currently in press with the journal *Rodriguesia*. She is currently supervising a Masters student, Livia Temponi, who is working on a floristic study of the Araceae of "Parque Estadual de Rio Doce" in Minas Gerais State. Temponi is working at the Universidade Federal de Viçosa in Minas Gerais State. Having recently finished her thesis she will begin a molecular study of *Anthurium* section *Urospadix*.

Maria de Lourdes Soares, at the Instituto de Pesquisas da Amazônia (INPA) in Manaus, works on the aroids of northern Brazil. Her Master's thesis (Universidade Federal Rural de Pernambuco, Recife) was a taxonomic survey of the species of *Philodendron* occurring in the Ducke Reserve north of Manaus (Soares, 1996; Soares & Mayo, 2001). She also published a general field guide treatment to the aroids of the Ducke Reserve (Soares & Mayo, 1999) and is



working on a detailed flora treatment for the same area. She has made a survey of the Araceae of the state of Amazonas based on collections in the INPA herbarium in Manaus (Soares, in prep). She currently has begun work on a revision of *Heteropsis* in Brazil for her Ph.D. thesis, based at INPA.

Ivanilza Moreira de Andrade works on the systematics of the Araceae of Northeast Brazil, especially the state of Ceará. She has a special interest in the ecological morphology and architecture of aroid climbers and studied three such species in Pernambuco for her Master's thesis at the Universidade Federal de Pernambuco in Recife (Andrade, 1996; Andrade & Mayo, 1998; Andrade & Mayo, in prep.). She is now working on the biosystematics of the Araceae of montane forests in northeast Brazil for her Ph.D. Ivanilza, along with Nadruz, Gonçalves, Sakuragui and Soares, made their debut to most of the International Aroid Society at the VIII International Aroid Conference in St. Louis (1999) where they all presented their research.

Alba Lins at the Museo Paraense Emilio Goeldi in Belem studies the anatomy of Amazonian aquatic aroids. Her Masters thesis (Universidade Federal do Rio Grande do Sul) was on root anatomy and morphology in *Montrichardia* (Lins, 1994; Lins & Oliveira, 1995) and more recently she has been working on *Urospatha* anatomy. She is now beginning her Ph.D. studies; also at the Universidade Federal do Rio Grande do Sul, Porto Alegre.

Other aroid workers in Brazil include Cicero Barros, from the Instituto de Meio Ambiente de Alagoas in Mutange, Maceió, Alagoas, who works with the aroids of the state of Alagoas. He completed his Masters thesis (Universidade Federal de Pernambuco) in 1998 on a survey of aroids from a relict forest reserve in the Atlantic Forest of that state of Northeast Brazil; Jorge Wachter, at the Universidade Federal do Rio Grande do Sul in Porto Alegre, who is interested in the aroids of southern Brazil and who discovered *Mangonia tweediana*; Ricardo Lainetti, from the Universidade Federal do Rio de Janeiro, who is interested in the pharmacological effects of *Xanthosoma* (specifically *X. violaceum*) and certain members of the Araceae; Luciedi Tostes, from the Universidade Estadual de São Paulo-Botucatu, who is working on the anatomy of the secretory structures and their significance in the biosystematics of the *Philodendron/P. selloum* complex; Livia G. Temponi, from the Universidade Federal de Viçosa, is working on a floristic inventory of aroids at the Rio Doce Reserve in Minas Gerais State. Finally, Emerson M. Vieira, from the Universidade Estadual de Campinas, and

Patricia Izan from the Universidade Sao Paulo, have published a study on the interaction of aroids and arboreal mammals in the Brazilian Atlantic rainforest (Vieira & Izar, 1999).

Two major projects currently under way that combine the efforts of Brazilian aroid systematics are the treatment for the Flora of São Paulo (Sakuragui, Nadruz Coelho, Gonçalves) and the Checklist of the Araceae of Brazil, coordinated by Nadruz Coelho.

In Asia a number of students are working on projects involved with Araceae. Melanie Medecilo is doing a revision of Philippine *Epipremnum* under the supervision of Domingo Madulid at the Philippine National Herbarium. Lim Sheh Ping, under the supervision of Ruth Kiew at the University of Malaya, is working with Araceae (and other families) occurring on the limestone formation in Sabah. Yasamni [monomial], also working at Kebun Raya (Bogor National Herbarium) under the direction of Alistair Hay, is working on terrestrial species of Araceae from Java. Baharuddin Sulaiman is working on the taxonomy of wetland Araceae in North Peninsular Malaysia at the Universiti Sains Malaysia on Penang Island in Malaysia. A Japanese botany student, Yasuko Mori, under the supervision of H. Okado, is working on pollination and population dynamics in *Furtadoa* in Sumatra and the Malay Peninsula.

In China, a large number of researchers working with Araceae made their international debut by presenting papers at the VI International Aroid Conference in Kunming. Many of these papers have now been presented in a special edition of the *Acta Botanica Yunnanica*. Some of these researchers are students or former students of Li Heng at the Kunming Institute of Botany, including: Peng Hua (Peng & Li, 1995; Peng & Li, 1998), Wang Ping-Li (Wang & Li, 1998), and Xiao Tiao-Jiang (Xiao *et al.*, 1998), Long Chun-Lin (Long & Li, 2000a; Long & Li, 2000b), and Xia Li-Fang (Xiao & Li, 1998; Wang & Li 1999). Others, such as Zhang Sheng-Lin, Liu Pei-Ying (discussed above) and Sun Yuan-Ming from the Southwest Agricultural University in Chongqing, presented papers (Zhang *et al.*, 1998), as did Guo Qiao-Sheng, Zhang Guo-Tai and Wang Kang-Cai from the Nanjing Agricultural University (Guo *et al.*, 1998). Finally, Yang Yong-Kang from the Yunnan Agricultural University in Kunming also presented a paper (Yang, 1998).

Jane Whitehill, formerly a student of Tom Croat, has done studies on

reproductive biology in Araceae (Whitehill, 1993) and has carried out preliminary investigations with the molecular biology of members of the former *Colocasioideae*.

A most impressive and useful work, which appeared in 2002 is the World Checklist and Bibliography of Araceae (and Acoraceae). The work was done by most existing family experts on Araceae and was ably edited by Rafael Covaerts and David G. Frodin (2002). In addition to a comprehensive and complete listing of the world's Araceae with references, distribution and habit, the work also contains a comprehensive list of all literature on Araceae as well as illustrations depicting one or more species in each genus. The table of contents includes a useful listing of all genera, including synonyms, fossil aroids and perhaps for the first time, it includes all of the genera of the Lemnoideae (formerly in Lemnaceae). Useful literature is aggregated according to sections making it easy to locate the pertinent literature.

Mark Gibernau and Denis Barabé from the University of Montreal have published papers dealing with pollination biology, including one describing thermogenesis in three species of *Philodendron* in French Guiana (Gibernau & Barabé, 2000). Gibernau and his coauthors Denis Barabé, Damien Labat, Phillippe Cerdan and Alain Dejean have a paper accepted for publication in the Journal of Tropical Ecology (Volume 19: 1–5. 2003). This one deals with the reproductive biology of *Montrichardia arborescens*. Gibernau, along with Roger S. Seymour and Craig R. White, published a brief, yet fascinating, article in Nature describing the relationship between species of scarab beetle pollinators and thermogenic flowers of *Philodendron solimoesense* (Seymour *et al.*, 2003). Papers on the floral odor of *Arum italicum* (Gibernau *et al.* 2004a) and a review of pollination in the genus *Arum* (Gibernau *et al.* 2004b) were recently published in *Aroideana*.

Jorge Lingan, a student at the Universidad de San Marcos is specializing on Araceae of Peru and has completed papers describing new species of Araceae in conjunction with Tom Croat (Croat, Lingan & Davila, in press); Croat, Lingan & Hayworth (in press); Croat & Lingan (in press); Lingan & Croat (in press). Jorge initiated his work with collecting in Madre de Dios but changed the focus of his thesis when he lost funding for that project and instead began working with Missouri Botanical Garden staff member Rodolfo Vásquez in the region of Oxapampa in the Department of Pasco. There he did his thesis on the genus *Anthurium* in the region. Now he is working with Tom Croat on the all the genera

in the region. He is the only person currently from Peru with a substantial interest in Araceae.

## GEOGRAPHICAL AREAS OF RESEARCH WITH ARACEAE

There are geographical parameters to current research. While Josef Bogner works primarily with generic problems and on small taxonomic groups throughout the world, most researchers concentrate on a single continent or sometimes a single country. A few workers, such as Croat, Grayum, Sheffer, and Mayo and his collaborators in Brazil, deal almost exclusively with neotropical genera. Mayo's principal involvement has been eastern Brazil, especially Bahía. Croat's principal involvement for the early part of his career was in Central America, but in the last decade he has been concentrating on revisionary and floristic work in South America.

A number of researchers are now heavily committed to Asia because of the Flora Malesiana project. These include Boyce, Hay, Hettterscheid, Murata, Nicolson, and E. Widjaja. Presently, there are more researchers working on the Araceae of Asia than in any other area. In addition to those already mentioned on the Flora Malesiana project, other researchers include Li Heng and Kao Pao-Chung in China, H. Ohashi, H. Okada and M. Hotta in Japan (and sometimes other areas such as Sumatra), M. Sivadasan and S. R. Yadav in India, and D. Sookchaloem in Thailand.

Floristic works are also being carried out in the neotropics. These include floras being prepared for the following geographic regions: G. S. Bunting (Araceae for the *Flora of Venezuela*), in Colombia, D. Bay and T. Croat, for the Flora of Bajo Calima in Valle Department, and T. Croat and J. Lake for the La Planada Reserve in Nariño Department; Chocó Department (Forero & Gentry, 1989). In Ecuador, Araceae treatments are being prepared for the *Flora of Ecuador* as well as for florulas at Reserva ENDESA (Croat & Rodriguez, 1995), in Pinchincha Province; Jatun Sacha, Napo Province; Río Guajalito, Pichincha Province, and for the Flora of the Guianas; M. Grayum (Araceae for the Costa Rica Manual project); G. Benevides (Ecuador) Flora La Favorita, Pichincha; and Simon Mayo and Marcus Nadruz who are doing floristic studies on the flora of Brazil. Mayo and Nadruz have an unpublished manuscript for a checklist of the Araceae of Brazil and Mayo has a similar checklist for the Araceae of Bahía State in Brazil.

Researchers working with European and Near Eastern Araceae include M. Bedalov working with *Arum*, H. Riedl with *Eminium* and K. Alpınar, Araceae in Turkey. Because of the paucity of Araceae in Africa, relatively little work has been done in mainland Africa although Bogner has worked extensively in adjacent Madagascar, and S. Ittenbach of the Bonn Botanical Garden is revising the *Amorphophallus* of Africa.

## FUTURE RESEARCH NEEDS

The following summary of the taxonomic needs, in so far as they pertain to the neotropics, is a synopsis of a more extensive analysis entitled "Taxonomic status of Neotropical Araceae" (Croat, 1994c).

The Araceae are not equally distributed throughout the world, being much more abundant in tropical areas. There are two major centers of species diversity, tropical Asia, with 44 indigenous genera, and tropical America, with 36 (Croat, 1979b). Of these, 33 (75%) are endemic to the American tropics and 32 (89%) are endemic to Asia. Africa, a less important center of species diversity, has only 19 indigenous genera of which 12 (63%) of them endemic.

Research with Araceae is also quite unequal on a worldwide basis. It has, for obvious reasons, been most intense in temperate areas, especially in North America, Europe and Japan because most work has been done by Europeans, Americans, or Japanese, respectively.

If, as expected, the current work with the Flora Malesiana project results in regional treatments of such large genera as *Amorphophallus*, *Homalomena*, *Pothos*, *Rhaphidophora*, and *Schismatoglottis*, the obvious priority for Asia would be to continue these studies to include India and other areas of Asia so that complete monographic revisions could be completed. Hettterscheid will independently complete his revision of *Amorphophalus* within the next few years. The balance of Asia, which includes such complex genera as *Aglaonema* (already revised once by Dan Nicolson [Nicolson, 1969]) *Alocasia*, *Arisaema*, *Homalomena*, *Pothos*, *Rhaphidophora*, *Scindapsus*, and *Schismatoglottis*, should prove no obstacle for the Flora Malesiana team now assembled. The revision of the Araceae for the Flora of China by Li Heng, Jin Murata, and perhaps others is opportune, given the strong impetus of the Flora Malesiana project. There are

areas where more fieldwork would be welcome, such as in Vietnam, Laos, Cambodia and especially Myanmar; areas long closed to most of the world's botanists, the latter two countries still closed today. Work in India (by M. Sivadasan) and Vietnam (Nguyen, Boyce, and Serebryanyi) is in preparation. Still, it seems logical that the Araceae of Asia and the mostly related continent of Australia might become quite well known within the next 25 years. Australia was thought to be well known until A. Hay discovered a batch of new species and a genus new to Asia. Described as the new genus *Lazarum*, Hay now believes it to be a new species of *Typhonium* (Hay, 1997b).

Africa is a lesser center of species diversity than Asia as noted above but many of the genera have only a few species and none are large. This should make the taxonomy of the area less complicated. Considerable floristic work took place in Africa in earlier colonial times but less floristic and monographic work is being done today with Araceae. Much of the continent is now relatively well known floristically, thanks to a modern revision of Tropical East Africa (Mayo, 1985a) and Madagascar (Bogner, 1972a, 1972b, 1973a, 1973b, 1975). However, there still are areas that need to be further explored, especially in Cameroon, Gabon, Central African Republic, and Congo (formerly Zaire). Except for the genus *Culcasia*, which is complex, fairly species-rich and in need of a modern revision, the continent of Africa by no means poses serious taxonomic problems for Araceae (Hepper, 1967).

Stephan Ittenbach, from the University of Bonn, under the supervision of Wolfram Lobin, has completed an as yet unpublished revision of the African species of *Amorphophallus*. *Anubias* has recently been revised (Crusio, 1979a, 1987; de Wit, 1990) and much of the genus *Stylochaeton* occurs in the region of the Flora of Tropical East Africa. A thorough study of the Araceae of the Ivory Coast (Knecht, 1983), a part of Tropical West Africa, appears to be relatively well known and well documented. This study, coupled with the relatively thorough revisions by Hepper (1968a) leaves me with the impression that even a massive collecting program would not yield much new information to science.

The flora of Europe and the Near East is by now well known due to a variety of works including G. Hegi (Hegi, 1909, 1939) and the revision of this work by H. Riedl (Riedl, 1979) as well as the more recently published *Blütenpflanzen Mitteleuropas* (Aichele & Schwegler, 1996). Other efforts include Riedl's own work on the *Flora of Iran* and the *Flora of Iraq* in the Near East

(Riedl, 1963, 1969, 1985), as well as works for Spain (Caballero, 1940); the Balkan Peninsula (Hayek, 1933); Iran (Assadi, 1989), Syria and Lebanon (Mouterde, 1966); Israel (Koach, 1988), a revision of *Arum* for the island of Crete (Greuter, 1984); the treatment for the *Flora Europaea* (Amaral Franco *et al.*, 1980) and Peter Boyce's work with the studies of Mediterranean genera (Boyce 1994a, 1993a). Floristic work in Eastern Europe includes that of Russia (Kuzeneva, 1935) and Bulgaria (Kuzmanov, 1964).

Sue Thompson has revised the Araceae for the *Flora of North America* (Thompson, 2000). D. G. Huttleston (1953) earlier published a study of North American species. Monographic work on *Arisaema* for North America was done by Huttleston (Huttleston, 1953), and by Blackwell and Blackwell at Miami University (Blackwell & Blackwell, 1974), and by M. Treiber at the University of North Carolina (Treiber, 1980). Araceae of the region has been well studied in a wide range of regional floras or checklists, e.g. North America (Shetler & Skog, 1878; Kartesz & Kartesz, 1980); Canada (Marie-Victorin, 1931), Nova Scotia (Roland & Smith, 1069); northern U.S. and Canada (Britton & Brown, 1970; Lazarides *et al.*, 1988); the Pacific Northwest (Hitchcock *et al.*, 1969; Hitchcock & Cronquist, 1973); California (Jepson, 1925; Thomas, 1961; Hickman, 1993); Montana (Dorn, 1988a); Arizona (Kearney & Peebles, 1964); Colorado (Harrington, 1954); Wyoming (Dorn, 1988b); Great Plains (Rydberg, 1932; Churchill, 1986); North Dakota (Kannowski, 1989; Stevens, 1950); South Dakota (van Bruggen, 1985); Kansas (Barkley, 1968; Bare, 1979; Brooks, 1986; Stevens, 1961); Wisconsin (Judziewicz, 1993; Wetter *et al.*, 2001); Michigan (Voss, 1972); Missouri (Steyermark, 1963; Yatskievych & Turner, 1990; Dennison, 1978; St. Louis area (Eisendrath, 1978); Ozarks [Missouri] (Leake & Leake, 1989); Illinois (Mohlenbrock, 1975); Oklahoma (Waterfall, 1972); Arkansas (Hunter, 1988; Hyatt, 1993; Smith, 1994); Alabama (Diamond & Freeman, 1993); Texas (Gould, 1962; Correll & Johnston, 1979; Hatch *et al.*, 1990); Mississippi (Fritsch, 1993; Lowe, 1921; Timme, 1989); the Carolinas (Radford, *et al.*, 1968); eastern North America (Fernald, 1950; Leck & Simpson, 1993; Gleason & Cronquist, 1991; Stalter *et al.*, 1993); Blue Ridge Mountains (Wofford, 1989; Ramsey *et al.*, 1993); southeastern USA (Small, 1933; Wilson, 1960; Duncan & Foote, 1975); southwestern USA (Correll & Correll, 1972); tropical Florida (Long & Lakela, 1971); central Florida (Wunderlin, 1982), and the Florida Panhandle (Clewell, 1985). Hawaii, politically a part of the United States, has only introduced species (Wagner *et al.*, 1990; Croat, 1994c).

## NEED FOR RESEARCH IN NEOTROPICS

While the paleotropics have more genera than the neotropics (61 versus 36), the neotropics is proportionately much richer in species with South America alone having roughly two-thirds of the 3200 species in the family. Croat's studies in Central and South America show that future priorities for taxonomic research with Araceae are clearly for systematic studies of the large and medium-sized genera in the neotropics, especially in South America, where the new and poorly known species often outnumber those having known names. In many areas, and for most genera investigated, large numbers of novelties occur. For example, for *Anthurium* of Panama, 54% of the taxa were new to science (Croat, 1986a); for *Anthurium* sect. *Pachyneurium*, 42% of taxa occurring in Central and South America were new (Croat, 1991a), for the revision of *Philodendron* subg. *Philodendron* of Central America (Croat, 1997), 62% of taxa were new, as were 40% of *Philodendron* subg. *Pteromischum* (Grayum, 1996), and 47% of *Dracontium* (Zhu & Croat, 2004, in press). Thus it seems that more emphasis and manpower and energy must be applied to research with the Araceae of the neotropics.

Our level of knowledge of the systematics of the neotropical Araceae also varies greatly from area to area, due largely to recent revisionary work or to the interest and area focused on by particular workers, e.g., G. S. Bunting in Mexico (Bunting, 1965) and Venezuela, Croat in Panama and Central America (Croat, 1978a, 1983a, 1986a, 1986b, 1988a, 1991a), and Croat & Grayum in Costa Rica. Central America is, in general, less species-rich than South America with species diversity generally increasing as one approaches South America (Croat, 1986a, 1986b). Though some parts of Central America, especially Panama, have shown unprecedented increases in the known aroid flora (Croat, 1985a), it is still much more well known than South America largely not only from the more prolonged effort by aroid taxonomists in the region, but also due to the fact that some parts of Central America are much less rich in species per unit area than many parts of South America; most notably the species-rich northwestern region of that continent (Croat, 1992a).

### CENTRAL AMERICA

Most of the earlier work in Central America was undertaken by P. C. Standley in a series of floristic works (Standley, 1927, 1928, 1933, 1937, 1944).



Others who contributed to floristic surveys of Central America include W. B. Hemsley (Hemsley, 1885), and for Mexico, Eizi Matuda (Matuda, 1954; Williams, 1981; Espejo & Lopez, 1993), [Veracruz] (Sosa & Gómez-Pompa, 1994).

The larger genera of Araceae in Central America have already been revised. These are *Anthurium* (Croat, 1983a, 1986a, 1991a) and *Philodendron* (Croat, 1997). Other middle-sized genera have recently been revised or at least have modern revisions. These include: *Syngonium* (Croat, 1981b), *Monstera* (Madison, 1977a), and *Spathiphyllum* (Bunting, 1960a). Revisions of *Rhodospatha* for the neotropics and *Dieffenbachia* for Central America are being prepared by Croat, and one for *Dieffenbachia* will soon be published. However, even in Central America some recently revised genera such as *Monstera* (Madison, 1977a) are now inadequate. New species, though fewer in number, are also now known for *Spathiphyllum*, *Syngonium*, and *Anthurium*, the latter two having been revised within the last 15 years (Croat, 1981b, 1983a, 1986a, 1991a). Croat is committed to complete the entire family for the Flora of Mesoamerica, which will constitute a revision of virtually all the Araceae of Mexico and Central America.

## WEST INDIES

The flora of the West Indies is much less species-rich and is in general well known. Other general non-flora papers that deal with West Indian taxa include: *Philodendron*, (Mayo, 1981), *Xanthosoma* (Stehlé, 1946), and the ecology and taxonomy of Trinidad Araceae (Simmonds, 1950a, 1950b; Mayo, 1986a). There are still significant taxonomic problems with some species of *Anthurium* in the Lesser Antilles. One of the most troublesome aspects of taxonomic studies in the West Indies is that the type specimens are either inadequate (need epitypification) or completely lacking all together (need neotypification), due to the fact that this region was among the first areas in the neotropics that was botanized.

## SOUTH AMERICA

While the aroid floras from some parts of South America, especially the Amazon basin, are reasonably well known, the species from the lower slopes on either side of the Andes and especially those species along the western slopes of the Andes in northwestern South America, are very poorly known and 50% or more of their species are new to science (Croat, 1985e, 1992a, 1995b). Some

areas for which floristic surveys have been conducted in the past 30 years are relatively well known. This is especially true of Venezuela, where extensive work has been done, especially by G. S. Bunting (Bunting, 1975, 1979, 1986a, 1988, 1988a, 1989) and also by Croat & Lambert (1987). The Venezuelan flora contains 266 species and an additional 25 subspecies or varieties.

The Guiana region is relatively well known at least in part because it is relatively species-poor rather than because of the extent of the collecting efforts. Suriname was, until recent years, the only part of the Guianas that received much attention in regard to Araceae, and largely due to the work of Jonker-Verhoef & Jonker (1953a, 1953b, 1966, 1968a, 1968b). Recently, the whole region is receiving more attention because of work on the Flora of the Guianas project and to the Araceae treatment being carried out by Croat. There are an estimated 121 species in that flora. In addition, Bunting (1995) has completed the Araceae treatment for the Flora of the Venezuelan Guyana, the Venezuelan counterpart of the Guianas flora. This flora treats 19 genera (including *Urospathella* G. S. Bunting considered by some as a synonym of *Urospatha*) and 177 species.

Another example of a relatively well-known area is the state of Bahía in Brazil where Simon Mayo and other members of the Kew Garden staff, especially R. Harley, have made a number of expeditions and are heavily devoted to the floristics of the state (Harley & Mayo, 1980; Mayo, 1984). Mayo has also prepared a revision of the Araceae of Bahía, and a checklist for all of Brazil. Any reference to the number of species in Brazil for any genus discussed in this paper relies heavily on this unpublished work. Mayo has also worked closely with many Brazilian botanists to encourage their participation in work with Araceae of Brazil (Mayo & Nadruz, 1992; Catharino & Olaio, 1990).

Parts of southern South America are by now also well-known and floristic treatments have been prepared for Argentina (Crisci, 1968, 1968a, 1971) and Paraguay (Croat & Mount, 1988). A floristic treatment has also been completed for the state of Santa Catarina (Reitz, 1957).

The *Flora of Peru* (Macbride, 1936), though falling short of giving an accurate picture of the species count for Peru, does come close to indicating the number of species actually described for Peru, since, except for *Anthurium* sect. *Pachyneurium* (Croat, 1991a), few groups have had many species described from Peru since MacBride's publication (Macbride, 1936). A more accurate accounting

of the number of species of Araceae in Peru is published in the *Catalogue of the Flowering Plants and Gymnosperms of Peru* (Croat, 1993). Though not a thorough revision of the species occurring in the country, this list takes into account all species of plants described for Peru as well as all species represented only by herbarium specimens that could be verified by experts for each family. The checklist contains 210 species of Araceae for Peru but does not include any unpublished names. Many new species remain to be described. New efforts to study the Araceae of Peru are being undertaken by Jorge Ligan (USM) who has collected in Madre de Dios and is working on his thesis at the Universidad de San Marcos on a project to study the Araceae of the region of Oxapampa in Pasco Department (see Ligan, J).

While there is no completed Araceae treatment for the flora of Ecuador, a recently published checklist for the Amazonian lowlands (Renner *et al.*, 1990) listed 92 species of Araceae (a few of them undescribed) and gave some indication of the species diversity of that part of Ecuador. Unfortunately the Amazonian lowlands represent one of the most species-poor portions of the country if its area is taken into account, due to the widespread nature of the species in that zone. A checklist for the entire flora of Ecuador has been prepared by Peter Jorgenson & S. Leon-Yanez at the Missouri Botanical Garden. Croat was responsible for editing the checklist of the Araceae treatment (Croat, 1999)

The lowland Amazon basin is also relatively well known, principally because of the fact that the species inhabiting the Amazon lowlands are normally wide-ranging and often common species. The vast Amazonian region lying between the Atlantic coast and the foothills of the Andes has moderately few, mostly wide-ranging species. Species diversity increases dramatically as one approaches the foothills of the Andes in the west. Species occurring on the lowermost slopes of the Andes tend to range widely in a north-south direction, often from Colombia to Bolivia and thus tend not to be endemic. However, some of the species of this region are currently believed to be endemic. The degree of endemism increases as elevation rises on the slopes of the Andes and as the terrain becomes more dissected with river valleys (Croat, 1994c).

To the east of the Amazon basin, especially in the Guiana Highlands and in eastern Brazil, from the state of Bahia south almost to Uruguay, the rate of endemism is much higher. Nearly all the species occurring in this region are endemic to eastern Brazil, and few range into the Amazon basin.

Though many species were described from eastern Brazil, by early aroid specialists, including Schott, K. Koch, and Engler, based on the early collecting efforts by botanists such as Glaziou, A. F. Regnell, Riedel, and others, these areas remain poorly known, especially because of the taxonomic complexity in such groups as *Anthurium* sect. *Urospadix* Engl., which dominates the area. Perhaps the only group of aroids well known in the region is members of the recently revised *Philodendron* subg. *Meconostigma* (Mayo, 1991a).

The truly temperate parts of the continent are devoid of aroids and the subtropical portions of the continent, while containing a number of small, frequently endemic genera in the tribe Spathicarpeae, are also relatively species-poor.

Species diversity is high throughout the South American Andes but especially along the northwestern slope extending from Chocó Province in Colombia and on both the eastern and western slopes in the Andes in the region of the equator and on the eastern slopes of the Andes in Peru. Species diversity is also relatively high in the Cordillera de Merida of western Venezuela but remarkably less so in the northern part of the Eastern Cordillera of Colombia and on the entire western flank of the Eastern Cordillera in Colombia (Croat, 1992a). Species diversity is also relatively low in the Central Cordillera of Colombia. High species diversity is correlated with high precipitation and with the absence of prolonged dry seasons.

Species richness is greatest between sea level and middle elevations to about 1500 meters. While some species may range to about 3750 m, diversity drops off dramatically above 2000 m. Seasonally dry areas, such as the central plateau of eastern Brazil and the lower Amazon basin, are relatively species-poor as are the generally treeless llanos of Venezuela.

Endemism is also especially high in the Andes of western South America, including the eastern range of the Andes that extends into Venezuela. Endemism is also high in the Guiana Highlands and in parts of North America, especially in Mexico and in lower Central America, in Costa Rica, and Panama. For example, Mexico, with 41 taxa of *Anthurium* has 26 endemic taxa. Guatemala has only three endemic species. Honduras and Nicaragua each have a single endemic species. Costa Rica has 68 taxa with 22 species endemic, and Panama has 150

species of which 82 species, 55% of the total, are considered endemic.

Because of the high rate of endemism and the very high speciation in many parts of the Andes, our taxonomic knowledge of all but a few areas of the Andes is poor. Although selected areas of the Colombian Andes, such as the region of Popayán in Cauca Department, the departments of Antioquia, and the department of Cundinamarca, especially around Bogota, were well collected in the late nineteenth century by collectors such as Lehmann, early enough to have their material included in the revisions of both Schott (1860) or Engler (1905a), many areas had not been collected until recent times.

Pichincha Province and a few other areas of Pacific coastal Ecuador were well collected by L. Sodiro (Sodiro, 1901a, 1901b, 1902-1903, 1903, 1905a-c, 1906, 1907, 1908a, 1908b) and 257 species (including 281 taxa) were described. Despite this, the region remains poorly known, largely because of the inability to locate and study his widely scattered and poorly documented collections. Some Sodiro specimens are deposited in European herbaria (Croat, 1991) but most collections are deposited in the poorly curated herbarium (QPLS) of the monastery in Quito, where Sodiro originally worked. The collections may not be borrowed and the conditions in the herbarium make their study there very difficult (Croat, 1991). Nevertheless some recent attempts at revisionary work have taken place in Ecuador in Pichincha Province. Floristic surveys of the Araceae have been made of the Reserva ENDESA on the western slopes of Volcán Pichincha (Croat & Rodríguez, 1995). This work, begun by Jimena Rodriguez de Salvador while a student at the Universidad Católica in Quito, was subsequently augmented by investigations by Croat. Other florulas are also being prepared as well and a comparison of six different florulas in Ecuador has been completed (Croat, 1995b).

A genus-by-genus account of the taxonomic status of neotropical genera and a discussion of poorly known floristic regions in the neotropics has been published elsewhere (Croat, 1994c).

## MOST POORLY KNOWN FLORISTIC REGIONS

Certainly among the richest areas on earth for Araceae are the Chocóan lowlands in northeastern Colombia and the western slopes of the Cordillera Occidental. Certain small parts of this area have been reasonably well collected

and other portions such as the Pacific slope of Cauca Department have scarcely been touched. The flora seems to be largely endemic and the number of undescribed species in the flora is astonishing. Other regions that are still poorly known are the western slopes of the Cordillera Oriente in Colombia, eastern and western slopes of the Ecuadorian Andes, especially in the northern part of the country, the eastern slopes of the Andes in southern Peru, especially in Zamora-Chinchiipe and far northern Peru, especially in the Department of Amazonas. All species in these areas are likely to be poorly known.

Taxonomically, the two largest genera, namely *Anthurium* and *Philodendron*, pose the largest difficulty. However, other genera such as *Monstera* and especially *Stenospermation* pose major taxonomic problems also. In addition, *Monstera*, though revised recently (Madison, 1977a), appears to still need taxonomic work, especially in South America. *Dieffenbachia* is being revised for Central America but remains very poorly known in South America. Both *Heteropsis* and *Urospatha*, though relatively small genera, are in need of revisions. Even *Spathiphyllum*, revised by Bunting (Bunting, 1960a) is in need of another revision.

## CONCLUSION

The Araceae, though the active subject of research by many botanists since the time of H. W. Schott, is still one of the most poorly known plant families. While considerable efforts are still needed to complete a revision of the Araceae of Asia, even more research is needed in the neotropics. While the family is reasonably well known in Central America and the West Indies, it remains poorly studied in the South America, especially in the region of the Andes. The current large team of scientists and the ever growing student population as well as the increased public interest in the horticulture and systematics of the family bode well for the ultimate goal of more completely understanding this remarkable group of plants.

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